Preserving our Night-time Skies

An exploratory study on the impact of light pollution and the potential for a new dark-sky site in County Mayo, Ireland

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I hereby declare that this dissertation is my own work.

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Abstract

Light pollution affects more than astronomy. It disrupts the natural cycle of night and day, and has consequences for our wildlife, our environment and our health.

Whilst this study acknowledges the importance of artificial lighting, it questions the awareness of light pollution in an Irish context. It examines how protecting the environment from the effects of light pollution may reap other benefits, such as helping to develop an area's full tourism potential.

A mixed-methodology approach was used, seeking both qualitative and quantitative data. The study identified and explored three strands of research: Awareness of Light Pollution, a Dark-sky Survey and an Outline Feasibility Study based on Dark-sky places in the UK and Ireland. The region of Ballycroy National Park, Co. Mayo, was chosen as the selected site for research.

The results indicated that the participants' awareness of light pollution was limited. The Dark-sky survey produced empirical data showing a pristine night-time sky over most, but not all, of the selected site. The Outline Feasibility Study provided a Dark-sky application project summary.

In conclusion, the results supported the expectation that the selected site is capable of qualifying for Dark-sky status. The study also concluded that increasing public awareness of light pollution would help to reduce its effect. Finally, the study recommends that, inter alia, light pollution is addressed at national level through policy and legislation.

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i. Dark-sky Park ("DSP")

A public land possessing an exceptional or distinguished quality of starry nights and a nocturnal environment that is specifically protected for its scientific, natural, educational, cultural heritage, and/or public enjoyment.

ii. Dark-sky Reserve ("DSR")

A public or private land of substantial size (of 700 km^2 about 173,000 acres) possessing an exceptional or distinguished quality of starry nights and a nocturnal environment that is specifically protected for its scientific, natural, educational, cultural heritage, and/or public enjoyment. The IDSA DSR is formed through a partnership of multiple landowners and/or administrators that have recognized the value of the starry night through regulations, formal agreements, and long-term planning. This is the route chosen by the South West Kerry Astronomy group in their application for Dark-sky Reserve status.

iii. Dark-sky Community ("DSC")

A town, city, municipality, or other legally organized community (such as a urban neighborhoods and subdivisions) that has shown exceptional dedication to the preservation of the night sky through the implementation and enforcement of quality lighting codes, dark-sky education, and citizen support of dark skies.

iv. International Dark-sky Association ("IDSA")

The recognised authority on light pollution (UNESCO, 2015), established in 1988. Based in the USA, this is a non-profit making organization and is funded by the grants, donations and membership fees.

v. Light at Night ("LAN")

Also known as ALAN, this is Artificial Light at Night.

vi. Light Pollution

According to the Oxford University Press Dictionaries, light pollution is "brightening of the night sky caused by street lights and other man-made sources, which has a disruptive effect on natural cycles and inhibits the observation of stars and planets". The Environmental Protection Agency UK has produced a booklet dedicated to light pollution, which defines it as: "Artificial light that is allowed to illuminate, or intrude upon, areas not intended to be lit". Perhaps the most referred to global authority for light pollution is the aforementioned IDSA and their glossary defines the term as simply "any adverse effect of artificial light". Most studies, including the IDSA's guidelines, highlight three most important aspects that contribute to the overall phrase of light pollution as illustrated in Figure 1.

1. Light Trespass/Nuisance - Where a light shine spills beyond the area it was intended to light and into property owned by another party.

2. Glare zone – this is ineffectual lighting where the direction of light is angled incorrectly. Consequently, glare shines into a person's eye and in some cases prevents sight of the scene it was set up to illuminate.

3. Sky Glow – consensus is that this is typically a yellow hue over towns and cities. This is expanded upon further in the "Dark Skies Action" article appearing in Oxford Journals (Walker & Murdin, 2003), as being caused by light shining up and not down.

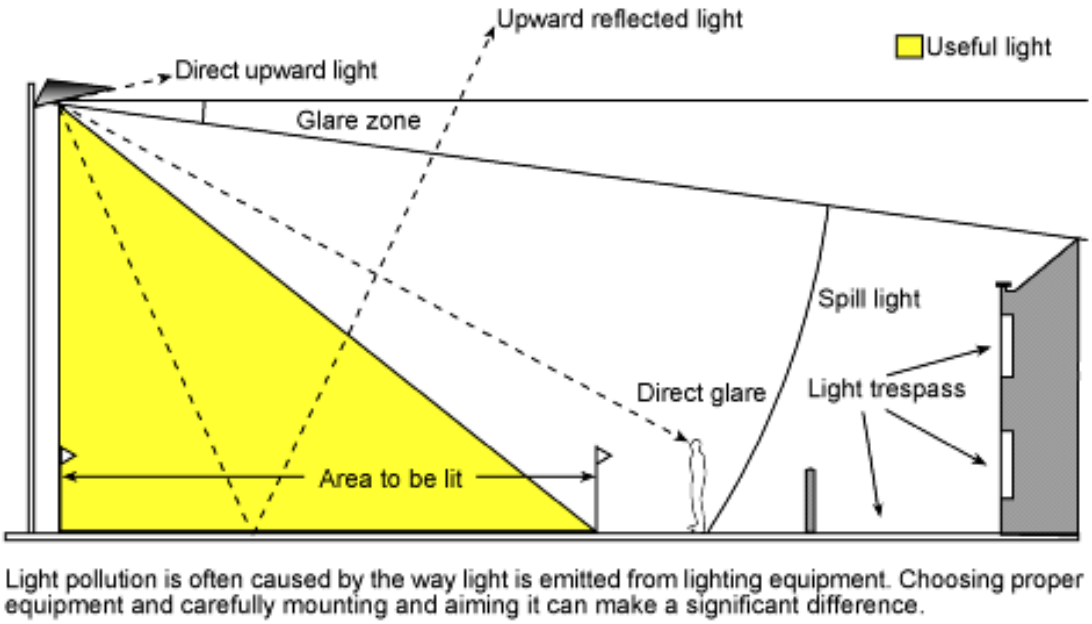


Figure 1: How light pollution occurs (Source: Institute of Lighting Engineers)

In addition to the three categories above, there are further definitions to add to the general term of light pollution. These include "Confusion; too many bright lights competing for attention and Light Waste; lights being left on all night or too bright for the task in hand" (Walker & Murdin, 2003).

vii. Lightscape Management Plan ("LMP")

A technical specification document required by the IDSA as part of an application for dark-sky status. This must include a complete inventory of all lighting within the proposed zone, together with information on how it will be managed effectively to negate the impact(s) of light pollution.

viii. National Parks and Wildlife Service ("NPWS")

A Heritage Division of the Department of Arts, Heritage and the Gaeltacht.

ix. Magnitudes per square arc second ("Mpsas")

Magnitudes are a measurement of an object's brightness. The term arc-second comes from an arc being divided up into seconds. There are 360 degrees in a circle, and each degree is divided into 60 minutes, and each minute is divided into 60 seconds. A square arc second has an angular area of one second by one second. The term magnitudes per square arc-second means that the brightness in magnitudes is spread out over a square arc second of the sky (Tekatch, 2015).

x. Natura 2000 Site

An extensive network of protected nature sites, established under the 1992 EU Habitats Directive. It is intended to protect Europe's most valued and threatened species and habitats. A Natura 2000 site may include a Special Area of Conservation and/or a Special Protected Area.

xi. Sky Quality Meter ("SQM")

This is a measurement tool used typically by astronomers to measure the quality of a starry sky darkness. Unihedron in Canada manufacture Sky Quality Meters.

1. Introduction

1.1 Background

"It is indeed a feeble light that reaches us from the starry sky. But what would human thought have achieved if we could not see the stars?" Jean Perrin [French Physicist 1879-1942]

As a society today, we are very familiar with artificial lighting. It illuminates our homes, office buildings, car parks, sports fields, advertising banners, and our roads and transport. Cities are visible from high above sea level due to the power of light. However, despite the obvious benefits of artificial lighting, there are negative consequences too, and one of the most prevalent is light pollution. The phrase "light pollution" is a modern term and would have made no sense in our recent history. We have taken quite a journey in a relatively short space of time since Edison's first light bulb, a mere 140 years ago. In those dark Victorian times, we were accustomed to dark streetscapes and dark skies above them. In ancient times, the desire to understand the stars was evident in such sites as the magnificent passage tomb at Newgrange. Yet today we are, as a society, unfamiliar with the night sky. Studies of light pollution have highlighted the lack of familiarity that many of us, at least in the northern hemisphere, now have with the natural dark-sky. When a 1994 earthquake cut power to Los Angeles, calls were made to the emergency services to report sightings of a "giant silvery cloud" in the dark-sky. For many LA residents, this was their first glimpse of the Milky Way, the view of which they were deprived of for decades in the city's urban sky (Chepesiuk, 2009).

However, not being able to view the Milky Way is a minor consequence of light pollution affecting our world today. Due to a globally expanding population, the issue of light pollution is going to have greater significance unless there is more action taken to understand and implement reasonable policies for sensible and sustainable lighting. Global maps taken from satellite night views clearly show that light pollution is far more evident in "developed" countries and those enjoying economic success. Therefore, research is becoming increasingly important to build public awareness on this subject.

In contrast, and on a more positive note, the concept of preserving the night-time sky is not entirely neglected. The Campaign to Protect Rural England targets light pollution as one of its major projects. Initiatives such as "dark-sky places" are starting to gain momentum, and many National Parks in the UK have received recognition of their starry sky quality by the International Dark-sky Association.

Having introduced the subject, this dissertation now looks at the questions arising and hypothesis behind the study area.

1.2 Research Hypothesis

In reviewing papers and articles for this dissertation, it became clear that the subjects of light pollution and dark-sky places reach out across a number of issues. However, the common theme connecting the two topics is the preservation of the night-time sky, and this is the essence of this research.

Therefore, the hypothesis is as follows:

"The night-time sky is worth preserving; this can be done through minimising the impact of light pollution and enhanced by the introduction of dark-sky places. As an exploratory study, the region of Ballycroy National Park will be looked at in the context of applying for dark-sky status."

1.3 Research Questions:

In establishing whether this hypothesis can be proven, a dark-sky survey and feasibility study will need to be undertaken. Within this realm, this research will look at local awareness of light pollution as well as existing dark-sky places, raising the following general questions:

- *What are the local attitudes to light pollution?*
- *Would there be support through local agencies for a dark-sky application?*
- *How compelling are the health, environmental and energy concerns surrounding light pollution?*
- *What benefits, if any, have existing dark-sky parks brought to the local community/environment?*
- *What are the qualifying criteria and what are the barriers to establishing a dark-sky place?*
-

In a context more specific to the selected site, a dark-sky survey will be undertaken to measure the level of light pollution and to investigate the following questions:

- *Can the Ballycroy National Park site satisfy dark-sky qualifying criteria?*

- *Is the National Parks and Wildlife Service ("NPWS") likely to support an application?*
- *What changes, if any, will need to be made to support such an application?*

1.4 Justification

The lack of public awareness of light pollution is one of the justifications for this paper and this ties into the increasing number of dark-sky places being established. Evidence, which will be discussed later in the literature review section, suggests that light pollution has an impact on many areas of life, including health, wildlife, environment, energy, economy, astronomy and general leisure. The issue of human health, effects on wildlife and a general waste of valuable energy are important reasons to take light pollution seriously. Some of these areas pose considerable concerns, yet this is an area that is currently under-researched in an Irish context. Light pollution is rarely mentioned in environmental policies here in Ireland and one of the objectives of this study is also to look at those policies that are in place (some county councils have mentioned light pollution plans) and establish whether there are plans to implement an all-island policy.

In the UK, public awareness of light pollution is becoming more prominent following popular programmes such as the BBC's "Stargazing" with Professor Brian Cox and Dara Ó Briain. The night sky has largely disappeared for many UK residents. One should be able to see 30 stars within the boundaries of the constellation of Orion on a dark night. In the UK only 2 percent of people can do

this (McGreevy, 2012). According to Stuart Lynn of Dark-sky Scotland, the UK has many areas of quality night sky and unsurprisingly, many of these areas have received Dark-sky designation for preservation from the International Dark-sky Association ("IDSA"). To date, there is only one such region in Ireland; The Kerry International Dark-sky Reserve. This does not mean that Kerry is the only region in Ireland that still has a quality dark-sky but it is the only area that has been assessed and taken steps to preserve its starry skies by limiting the effect of light pollution. Further investigation is required to establish whether the Ballycroy National Park and surrounding Nephin Wilderness region here in Mayo is also a potential dark-sky zone. This study will also look at the support for such a project and ascertain whether this is a viable proposal for the region.

Having established the background to this research paper and key concepts that it will be focused on, it is now appropriate to move onto the main section of the paper, which is the Literature Review.

2. The Literature Review

2.1 Introduction

This chapter presents a documentary analysis and review of literature selected by the author for the purpose of this research. It was necessary to include literature ranging from academic fields as well as from media sources in order to gain a broad understanding of the topic of light pollution and its impact. The body of literature surrounding the dark-sky theme is limited due to the evolving nature of the subject. Nevertheless, progress has been made since this study commenced through contacting individual experts in the field of astro-physics, authors on light pollution and dark-sky preservation, as well as governmental agencies and departments.

The structure of the literature review follows the chronological order of research undertaken for this study. The themes examined include; the effects of light pollution – public safety; human health matters; the impact on wildlife; energy and environmental issues; policies and solutions to minimise light pollution; astro-tourism. Lastly, it will look at the emerging body of literature relating to dark-sky projects within UK and Ireland and their educational benefits.

2.2 The Effects of Light Pollution

In this section, the issue of public safety, health and environmental impacts of light pollution are discussed, drawing from a variety of sources, which

overwhelmingly point to the negative impacts of light pollution. However, it is important to strike a balanced view and remind the reader that this report recognises the requirement and benefit of having artificial light in our society. It is lighting at the wrong place or at the wrong time that is of concern, as well as the wrong type of lighting for the intended purpose, and this is what is considered light pollution.

2.2.1 Public Safety and Crime

This theme examines the link between improved street lighting and crime. It would be a fair assumption that, if asked, most members of the public would say that street lighting adds to their feeling of safety. Research has found contrary views on public safety issues as a result of too much or too little artificial light. There appears to be a gap in the definitive analysis of whether artificial lighting at night actually reduces crime. The UK's College of Policing has used the research works of Farrington and Welsh to produce their "What Works Briefing" (College of Policing Limited, 2008). This online newsletter indicates that lighting at night (LAN) enhances the safety and security of the public. In an interview with The Sunday Times, criminologist Dr. Kate Painter indicates that although inner city crime figures may have been reduced through enhanced lighting, increased LAN in rural areas may have the opposite effect "You need light to commit a crime. In the dark a torch can look highly suspicious" (Clover, 2010).

Figures showing that increased street lighting produced a 20% crime reduction (Farrington & Welsh, 2008), were criticized by Leeds statistician, Paul Marchant, for not including all relevant research in its systemic review. In his somewhat

controversial paper, Marchant disputes the claim that street lighting deters crime and goes on to cite that, some of this research was funded by lighting companies (Marchant, 2010). Clearly, there are polarised views on the subject of street lighting.

The UK's Home Office Crime Prevention Unit concludes that; whereas improved street lighting might reduce the impact of *fear* of crime, it may not necessarily reduce crime itself (Atkins, Husain and Storey, 1991).

Further studies by academics at Cambridge University found that dimming lights in Cornwall by 25% had no effect on crime (The Economist, 2012). There are several trial projects running in Britain to turn off street lighting between midnight and 05:30. In Essex, this has been deemed a success, leading to similar experiments by other UK councils (Espey, White & McCauley, 2012). However, some residents in Essex have expressed dissatisfaction with this policy (Echo News, 2015).

Home security lights are commonly found to produce light pollution in the form of glare. In these cases, the lights are positioned poorly and, ironically, can actually hide what they are intended to reveal. This could mean that an intruder, who would be spotted under a correctly fitted light, would now be hidden by the very security measure intended to highlight him/her (Espey et al., 2012) see Figure 2.

Overly bright light can mask intruders.

With the light shielded, the intruder is easily seen.

Figure 2: Good vs Bad Lighting (Source: IDSA Safety Brochure)

In concluding this section on public safety and crime, it is appropriate to remind the reader that this research seeks to strike a balanced view. Some of the arguments raised in the literature included may appear to go beyond the scope

and context of this research. However, their inclusion was deemed relevant to highlight the depth of research on what initially appears a simple assumption; that light equals safety.

2.2.2 Health Matters

Moving to a new theme, research has highlighted the links between light pollution and negative health effects, which pose cause for concern. So, how can light pollution affect our health? Our daily life cycle has evolved in nature's light settings of 12 hours of light and 12 hours of dark, depending upon season and latitude (Stevens, 2009). These cycles regulating our cellular and physiological processes are known as our circadian clock. It is this master clock that controls our melatonin production. An increasing volume of research indicates that time spent in artificial light exposes our retina to photons that can affect our circadian clock. This is linked to several medical disorders including depression, insomnia, cardiovascular disease and cancer (Chepesiuk, 2009). This is echoed in an article in the National Geographic which states that "the oscillation of waking and sleep in our lives – one of our circadian rhythms, is nothing less than a biological expression of the regular oscillation of light on Earth. Altering them is like altering gravity" (Klinkenborg, 2008).

A study conducted in Israel by the University of Haifa in 2008, compared satellite photos of artificial lights at night in communities; with a map detailing the distribution of breast cancer cases. Results showed a significant correlation between outdoor artificial light and breast cancer. Women living in neighbourhoods where it was bright enough to read a book outside at midnight,

had a 73% higher risk of developing breast cancer than those residing in areas with low outdoor artificial lighting (Chepesiuk, 2009).

In his research paper Dr. Richard Stevens of the University of Connecticut Health Centre, agrees that LAN may account for increasing risks of breast cancer through the suppression of melatonin production. He also notes that the International Agency for Research on Cancer (IARC) has classified shift work as a probable human carcinogen, due to the impact on sleep patterns (Stevens, 2009).

In 2012 the American Medical Association adopted a policy statement on adverse health effects of night-time lighting (Stevens et al., 2013). This adds weight to a growing body of research suggesting there are significant health concerns linking breast cancer increases to the use of light at night.

Other research, indicating that that artificial light at night may have links to depression is interesting, although a contradiction to research on Seasonal Affective Disorder (SAD), which indicated that extending the photoperiod with bright artificial light has an antidepressant effect (Rosenthal et al., 1984). This is most likely due to the colour of lighting bulb used (Wighton, 2013).

The scientific community is studying the range of disorders associated with exposure to too much artificial light at night. Although it has not been proven that LAN causes cancer, there is sufficient evidence to warrant significant research in this area.

In examining the health implications from excessive exposure to LAN, it is also relevant to mention the possible benefits from enhanced street lighting. For example, personal observations of recreational activities at nearby Lough Lannagh (a publicly owned parkland in the centre of Castlebar, County Mayo), saw an increase in usage of the facility for evening exercise regimes following the installation of street lighting. This reminds us that it is not necessarily the light that is the problem but in most cases the installation and direction.

2.2.3 Impact on Wildlife and the Environment

Studies show that it is not just humans who are affected by light pollution; mammals, invertebrates, birds and amphibians are also impacted. Evidence suggests that migration patterns are affected significantly. Nocturnal birds use the moon and stars to aid navigation in their migration periods and are disorientated when they fly into areas affected by light pollution (Figure 3). In his draft report "Light Pollution in Ireland", Prof. Brian Espey of Trinity College, Dublin quotes statistics of D. Malakoff's paper "Faulty Towers" stating some 4-5 million birds per year are killed colliding into tall buildings. There are two reasons for the collisions. Firstly, "blind collision"; where birds flying in poor conditions do not see the building in time to change course. Secondly, in low cloud, the structure lights cause reflection off water particles creating confusion for nocturnal navigation (Deda, Elbertzhagen and & Klussmann, 2007). Toronto is a city taking light pollution seriously in relation to its ecological effect. The Fatal Light Awareness Program, set up as a non-profit organisation, has tracked

that in Toronto alone, more than 42,000 bird collisions occurred since 1993 to 2010. In 2007, it issued Bird-Friendly Development Guidelines to urban planners and builders to emphasize the need for good lighting design and for those offices already in operation, it has issued recommendations to workers to draw blinds at night to minimize the unnecessary light output of the building (Claudio, 2009).

Figure 3: Ecological & Astronomical Light Pollution - Source: (Longcore & Rich, 2004)

In Ireland, it is not just the light pollution from tall buildings that affects our birdlife. The newer brighter lights installed in our towns affect birds at night-time. Robins, for example, are often heard singing at night near to brightly lit street lamps. The timing of their, and other common songbirds', dawn chorus is affected by artificial lights (Kempenaers, da Silva & Valcu, 2015).

Security lights placed too close to nesting holes will affect birds such as swifts, from identifying their nest entrance due to lighting glare (L Huxley 2015, pers. comm., 9 Jan).

In gathering articles for this section, the researcher considered the impact on marine life and contacted the Marine Institute's base in nearby Furnace, Newport. The response was inconclusive, local scientists had not encountered evidence that light pollution had negatively affected Salmon (for example). However, it is known that Silver Eels migrate on new moons (i.e. darkest nights) and would be light-sensitive (E de Ayto 2015, pers. comm)

Many nocturnal mammals are also affected by artificial lighting interfering with their predator / prey relationships. For example, species that are repelled by light such as lesser horseshoe and long eared bats, feed on insects at night. Yet those insects are drawn to bright lights and thus are unreachable for the bats to feed upon. This may have contributed to the increase of the common pipistrelle bats in some areas (Klinkenborg, 2008), as this species is not so light sensitive. Street lamps hosting thousands of insects make an attractive feeding ground for pipistrelles. Moths have the opposite problem, as their gravitation towards light makes them vulnerable to prey and subject to increased predation (Espey et al., 2012). In Ireland, bats are protected under the 1976 Wildlife Act and 2000 Amendment. Bat Conservation Ireland has produced a leaflet entitled "Bats & Lighting" which provides guidance notes for planners and developers on how to minimize the light impact on bats (2010).

Amphibians and reptiles are also affected – in particular, nesting sea turtles. Typically they would seek dark beaches for nesting and these are becoming harder to find. Also, their hatchlings, which gravitate towards the brighter sea horizon, are attracted to the artificial light, rather than moonlight and are often killed on the roads. In the United States, lost hatchlings in Florida alone have numbered among the hundreds of thousands (Klinkenborg, 2008) and a Marine Turtle Protection code has been put in place to rectify this. Since 2008, further states in the US have implemented lighting policies to protect sea turtles, according to the Florida Wildlife Conservation Commission (Claudio, 2009).

There is also considerable evidence to show that artificial lighting has an impact on flora. Moths, mentioned previously, are pollinators and thus part of the dispersion cycle. Therefore, their reduced survival has a knock-on effect on some plant life. Studies show that some 150 insects can be killed by a single streetlight per night. Ireland has over 400,000 streetlights, making the potential for 60 million insects to be lost per night (Espey et al., 2012). Darkness is also a key requirement for plants and their development. They measure and react to the duration of night-time and, for some plants, over illumination is measured as two nights instead of one. Consequently flowering and developmental patterns are disrupted. Similarly, trees adjust to seasonal alterations and artificial light hinders this with the result that leaves are not shed in the normal natural pattern (Deda et al., 2007).

Having established the impact of light pollution on wildlife, health and environmental, this report now moves to the issue of energy and financial implications.

2.2.4 Energy Waste and Economic Cost

Studies also show that poor lighting design leads to additional electrical energy consumption and thus to increased carbon dioxide emissions and ultimately, global warming (Galloway, Olsen & Mitchell, 2009).

In Britain, local authorities are starting to take action to reduce costs in operating street lighting. Interestingly, it is the economic effect that has prompted this action, and not a consideration of health benefits or ecological impacts. Street lighting in Hertfordshire is being reduced by approximately 70% of its operating time, which the scheme intends will save 35% on energy bills or £1.3m per year (The Economist, 2012). The Sustainable Energy Authority of Ireland ("SEAI") published a report on the energy efficiency of public lighting. It stated that there is scope for up to 30% of energy to be saved by 2020, through the integration of design, new installation and maintenance (2011). The EU's target for energy reduction by 2020 is 20% (European Commission, 2011). At the time of writing, it is not certain that Ireland will make this target. The SEAI attributes public lighting costs in Ireland to approximately €35 million per year, producing over 110,000 tonnes of carbon dioxide p.a. In 2010, water services accounted for 53% of electricity consumed by Ireland's local authorities. At 30%, public lighting was the second largest expenditure (2012). Given that water charges will soon be removed from local authorities expenditure, this brings

public lighting costs under higher scrutiny. In county Mayo alone, unmetered electricity (street lights) costs reached almost €1 million for 2014, excluding the maintenance contract (Mayo Co.Co. 2015, pers. comm., 16 Mar).

Having examined the effects of light pollution, this report now moves on to the next section; Policies.

2.3 Policies

From the research looked at so far, it would appear that the policies in place either do not recognise the significance of light pollution or those policies are not being enforced. It is quite likely that the significance is not fully recognised as, already mentioned above, light pollution is a relatively new form of pollution, and artificial lighting is clearly a requirement in today's world.

In the UK, the Department of the Environment, Food and Rural Affairs published a policy update in December 2013. In its introduction, this policy acknowledges that artificial light in the form of light pollution is not only wasted energy but harmful to wildlife and detracts from the enjoyment of the night sky. Only the briefest mention of risks to human health is included. This may be due to the lack of evidential research in the area, or perhaps a reluctance to publish for fear of raising public alarm.

One of the initiatives that arose from the policy amendment was to improve awareness within the general public. Much of the occurrence of light trespass is

from privately owned home lighting systems. By distributing a leaflet entitled "Getting Lighting Right" to retail organisations and local authorities it is hoped that the general public will benefit from energy saving and nuisance reduction to others. Similarly the city of Armagh, home of the oldest continuously functioning astronomical research institute in the UK, has included a "Right Light" policy in its guidelines on light pollution, which it hopes will address the effects of light pollution, and also lead to increased astro-tourism numbers (Bailey & Apostolos, 2007). Armagh has its own Observatory and Planetarium and is one of the leading centres for astronomical education on the island of Ireland. It was in Armagh that the Ninth European Symposium for the Protection of the Night was hosted in 2009. This event (attended by government officials, as well as astronomers and enthusiasts) raised awareness of the issue of light pollution in Ireland. It initiated research into the subject from an Irish perspective (B Espey 2015, pers. comm., 16 Feb).

Residents affected by light pollution in the UK have some course of action through the Clean Neighbourhoods and Environment Act 2005, which classifies light pollution under its nuisance provisions. The UK Environmental Protection agency has also published guidelines on Light Pollution for the general public to increase understanding and awareness. In comparison, according to the EPA here in Ireland (EPA 2014, pers. comm. 25 Nov.), light pollution is dealt through the planning process. Some local authorities (Kerry and Clare for example) have light pollution prevention suggestions in their Development Plans but this is far from nationwide and at the discretion of the local authority. Looking abroad,

there is national legislation to prevent light pollution in France, Slovenia and some regions of Italy (Morgan-Taylor, 2013). The Chilean Government recognised light pollution through policy inclusion as far back as 1998. They have recently taken a step further. In 2012, Chile adopted legislative measures to restrict blue rich outdoor lighting, in recognition of its impact to ecology and human health (Bishop, 2014).

A 2012 report by Tomás Bradley (employee of An Taisce) recommends a case for protection of the Dublin hinterland night-time sky through Planning and Development Acts. Adoption of these planning proposals would be a considerable breakthrough for controlling light pollution nationwide (Bradley, 2012).

An Taisce, the National Trust for Ireland, recognises the use of artificial lighting for roads, security, enhancement of buildings and outdoor facilities, but also acknowledges the need to implement an all-island management strategy (T Bradley 2015, pers. comm., 5 Feb.). Similarly, the Department of the Environment, agrees that light pollution should be reduced, in order to minimise the effect on wildlife, and advocates the conservation of energy. However, legislation affecting such environmental issues is unlikely to be adopted until it is agreed at an international level. This is due to the cross-border impact of many environmental pollutants (C O'Brien 2015, pers. comm., 2015).

2.4 Solutions

This section contains suggestions, researched from various sources, on how light pollution can be reduced. Some of these suggestions may appear a little ahead of their time, but as they are being tested in actual locations, warrant inclusion in this study;

2.4.1 Intelligent Light Systems

This is a form of wireless technology whereby streetlamps are controlled by individuals according to circumstance and need. At a basic level, this may be in response to a bright light shining into a bedroom causing sleep deprivation. Sensors, texting and email can control the light and there are suggestions that this could even generate revenue for councils from text controls (Winterman, 2012). There are obvious disadvantages in allowing such individual control and this may lead to a nuisance of lights on/lights off, proving more intrusive than a continuous light.

2.4.2 Light Emitting Diodes (LEDs)

As an alternative to sodium lamps, LEDs have longer life and are relatively inexpensive to install. They are also being produced with controls on the dispersal of lumens (i.e. preventing glare and unnecessary uplighting). However, whereas there are obvious benefits in saving money and energy there are further issues to be considered as studies show that the shade of light can have further impact. For example, unfiltered LED powered lighting creates a blue-rich light that may affect the circadian function of animals and humans (Beatty, 2010). The blue hue interferes with our circadian clock more so than other bulb colours

such as red, according to Professor Richard Stevens, cancer epidemiologist from the University of Connecticut Health Centre (Wighton, 2013).

Another counter-productive result from utilizing these energy-efficient lights, is that there is the risk that the saving in costs may tempt authorities to increase the illumination to previously unlit areas. Thus, still leaving the problem of surplus lighting at night (Kyba, Hanel, Holker, 2014).

2.4.3 Appropriate Lighting Policies

Adopting policies to address light pollution as a community, with the power to enforce changes if necessary, is a reasonable approach and should be part of town council planning strategies nationwide. Right Light policies, such as the one in Armagh, will also assist in education and awareness. The Sustainable Energy Authority of Ireland (2011) issued guidelines on energy saving and lighting design home security systems, which are often the root of most light trespass and nuisance lighting issues. The lack of legislation has been discussed earlier and in its absence, adopting a local policy approach would at least help to combat local levels of light pollution.

2.4.4 Education and Personal Responsibility

As with any other form of pollution, personal responsibility is a factor in how it is controlled. The recycling of waste is now fairly common within most Irish households. This practice is a relatively recent introduction and is in response to improved education on the matter of waste and better policy implementation. The same can be achieved in response to better education on light pollution.

The solutions discussed above, address most domestic and community based light pollution problems. However, the subject of Dark-sky places, which preserve the quality of our pristine skies, has not been explored, and this is the key theme for the next section.

2.5 Protecting the Night Sky

2.5.1 Dark-sky Places

Branded as Dark-sky zones by the IDSA, these "optically clean" places are now a sanctuary for astronomers, both amateur and professional (Smith, 2010). The first ever Dark-sky Park was in 2007 in Utah's Natural Bridges National Monument Park. Since then such regions have popped up across the world.

Dark-sky zones have made news headlines in Ireland due to the recognition of South West Kerry as an International Dark-sky Reserve by the IDSA in January 2014. The Kerry International Dark-sky Reserve encompasses an area of 700 square kilometres. This ambitious project incorporates several villages and two towns, all of which are included in a lightscape management plan to minimize light pollution and preserve its pristine night skies. The core zone (i.e. the darkest and most light pollution free zone), is 200 square kilometers and has exceptional measurements of darkness (Ormonde, 2013). This region was awarded Gold Tier status, making it the first Dark-sky Reserve in the northern hemisphere to obtain such a high accolade. It is worth noting that there are

several Dark-sky Parks in Europe that have achieved gold tier rating, but these qualify under different criteria to the Dark-sky Reserve.

Achieving any tier of rating for a Dark-sky zone is commendable and, from looking at aerial night-time photographs of UK, Ireland and Europe, it would appear that Ireland has one of the best Dark-sky potentials within its boundaries (see Figure 4). Although still early days, Kerry has already benefited from its award by attracting astro-tourists (J Ormond 2014, pers. comm 5 Oct) and similar success has been afforded the UK Dark-sky parks and reserves.

Recently the 10,000 hectare region in North Mayo, Wild Nephin, was recognized as a Wilderness Park. Surrounded by mountains on its southern side and Ballycroy National Park with acres of pristine Atlantic blanket bog to the north, this region has considerable potential for Dark-sky recognition. The map of Ireland's light pollution in Figure 4, indicates this region could be the best Dark-sky area in the country as there are no brightly lit towns or cities within close proximity. This area is well known for its remoteness, and the Nephin range of mountains are famously quoted in the words of Robert L. Praeger as the "loneliest place in this country" (1937). However, it could be argued that by granting special "status" to these expansive land masses such as "wilderness" or "dark-sky", it is merely creating a branding for promoting an existing asset, rather than really creating something new in terms of a conservation concept. Although motivated by the potential for economic benefit from tourism, the decision to create a Dark-sky place will have positive results for the local environment and conservation.

The answer really lies in how willing we are, as a society, to preserve natural asset of a Dark-sky and this leads to the next section on culture and heritage.

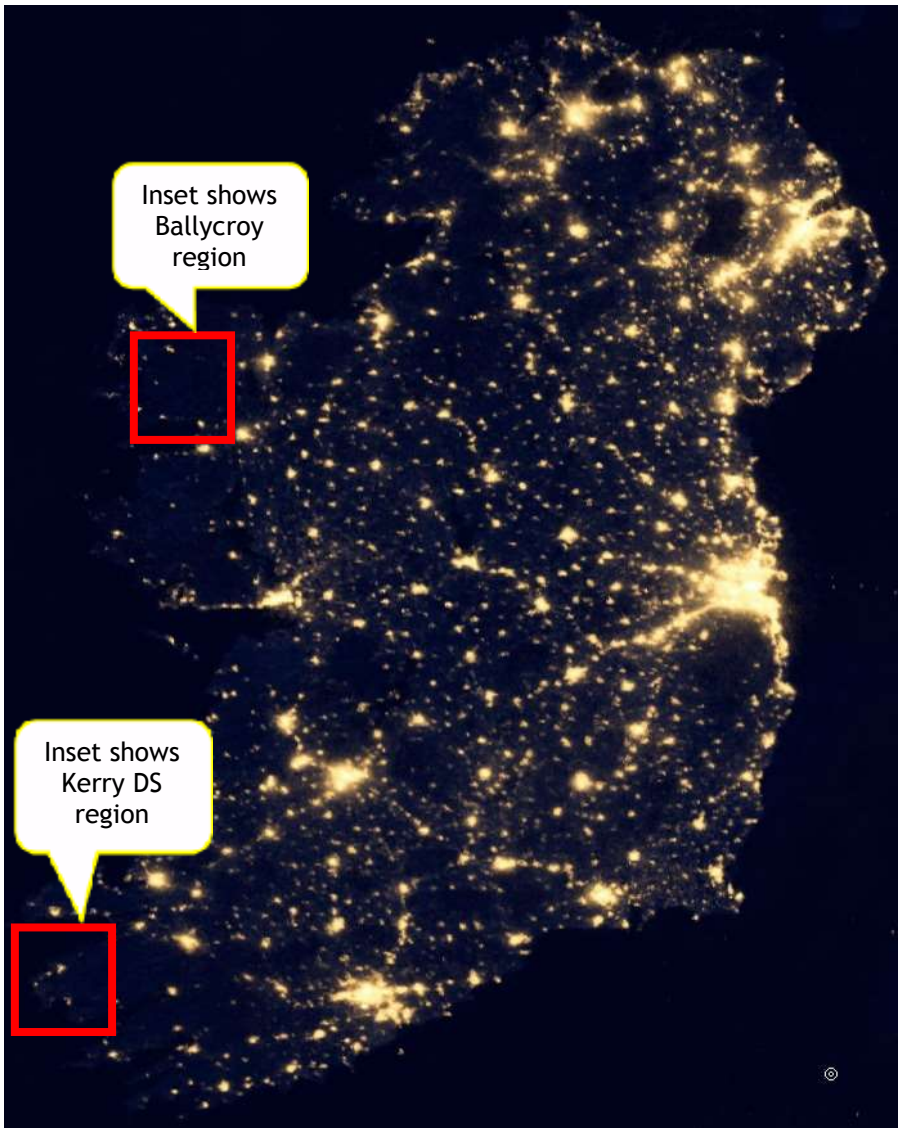


Figure 4: Light Pollution Map of Ireland (Source

2.5.2 Culture and Heritage

Our disappearing night sky is worrying to many astronomers, but it is not just those sky watchers who should have concerns. The Dark-sky has influenced

human culture, philosophy, religion, science and art (Bradley, 2012). Without protection, we risk losing our ceiling of stars to the yellow haze that we have become accustomed to seeing over the great cities of our modern world. The night-time sky may not be traditionally considered our heritage; indeed it does not merit a mention on the website of The Heritage Council (2014). Yet it is one constant, panoramic view that has remained "untouched" by man longer than any other environmental scene and is recognised by international heritage organisations.

UNESCO's World Heritage Convention supports a website dedicated to Astronomical Heritage. This is a term referring to evidence of ancient astronomy in the form of tangible remains, such as monuments, sites and landscapes. The website includes a global map of astronomical heritage sites such as Britain's Stonehenge. Interestingly, Ireland's sites of Newgrange and Armagh Observatory are among those included on the site's Irish Astronomy Trail (Ruggles, 2010).

Putting a cultural value on the night is a subjective concept. However, Ludwig Wittgenstein, the famous Austrian philosopher of the twentieth century put it succinctly in his quote "I can only think clearly in the dark. In Connemara, I have found one of the last pools of darkness in Europe" (Robinson, 2008).

In his report for An Taisce, entitled "Protecting the Night Sky on the Urban Fringe of Dublin", Tómas Bradley has used a process called The Burra Charter in his methodology to evaluate the cultural significance of the night skies on the urban fringe of Dublin (2012). This is not specific to astronomy or Dark-sky

places. However, the principles and procedures of it could be applied to a wide range of conservation projects such as monuments, archaeological sites, a whole district or a region. It covers a sequence of investigations and actions leading to policy management and recommendations, and it demonstrates how values can be created for our cultural heritage.

2.5.3 Astro-tourism

The UK obviously has a bigger "problem" of light pollution than Ireland, due to its large population and urban places requiring street lighting. However, the appearance of Dark-sky places is growing quickly in the UK, indicating that protective measures and recognition is rapidly taking shape. Media articles are regularly covering new Dark-sky applications; most recently the South Downs (BBC, 2014) and Cranbourne Chase (an Outstanding Area of Natural Beauty in Wiltshire) has applied for Dark-sky reserve conservation with the IDSA.

Astro-tourism has grown since the recognition of parks such as Galloway Park in Scotland, which was named the UK's first Dark-sky Park in 2009 (Lane, 2011). In this article, the author looks at the surge in tourism since the Dark-sky award, which saw a jump in visitors with 77% of local B&B owners reporting increased business. People who visit national parks in daytime such as families, hikers, nature-lovers, tend to also have a passing interest in the night-time sky, according to Allan Trow of Dark-sky Wales in his interview with the BBC News Magazine in 2011.

The success of dark-sky zones cannot be fully assessed without reviewing the attraction they hold for the tourist market. An increasing number of newspaper

articles have reported on the boom in Dark-sky tourism. Chris Tighe of the Financial Times reported on the success of tourist numbers since the opening of the Galloway Forest Park, in his March 2012 article.

There are a number of similar articles, including many on the announcement of the Kerry Dark-sky Reserve, where numbers of astro-tourists have also increased (Lucey, 2014).

2.5.4 Dark-sky Surveys

In previous sections, it has been mentioned that the IDSA is the official authority to grant Dark-sky status to a place. Naturally, it is taken for granted that the region must be dark but a survey must be undertaken to ascertain the average darkness. One of the ways to do this is by gauging the faintest Naked Eye Limiting Magnitude ("NELM") of stars (Griffiths, 2013). This method identifies the magnitude of the faintest star an observer can discern, under given sky conditions. The limiting magnitude depends strongly on sky transparency and the observer's experience. British Astronomer Steve Owens (who also worked on the Kerry Dark-sky project), has developed an interpretive flow chart (see Appendix i) Figure 25, which assigns the visual description to a Bortle scale[1] measurement for classifying the quality of the skies seen. This is a useful tool but relies upon the user having some knowledge of astronomy.

[1] *Bortle Scale is a nine level numeric scale that measures the night sky's brightness at a particular location. It is attributed to John E Bortle who first published it in 2001 (Owens, 2012).*

In his Guardian science blog, Owens reports on how he will use a methodology combining SQM readings as well as the NELM method to conduct a survey on the island of St Helena (Owens, 2012).

The IDSA's website explains the qualifying methods that may be used for a Dark-sky application and these will be expanded upon in the Methodology Chapter of this dissertation.

In the aforementioned article, Steve Owens cites tourism as the main reason for applying for a Dark-sky status (2012). This is an interesting view and probably the most genuine reason that authorities seek Dark-sky status, as opposed to recognizing the value that a Dark-sky site may have in combating, and raising the awareness of light pollution.

Considerable administrative work and a commitment to ongoing monitoring is required in order to qualify for Dark-sky status, but still a growing number places are achieving it. In writing "A truly dark-sky is a breathtaking experience", authors Martin Morgan-Taylor and Derek McNally (2012) seem to believe the effort is worthwhile, and it seems others agree. At the time of writing, there are four dark-sky zones dotted around the UK. These are located in Brecon Beacons (South Wales), Exmoor, Northumberland and Scotland with a further two applications currently in progress from locations in the south of England.

2.6 Conclusion

This literature review has looked at how light pollution affects our daily life. In exploring the effects of light pollution, the research included important health

issues, with a particular focus on the potential carcinogenic links. Although of a lesser concern than human health, the threat to biodiversity caused by light pollution is not an area to be ignored as this problem will grow if it is not addressed.

Research has revealed that the consequences of light pollution are not adequately addressed by policy or general knowledge. The financial costs and energy usage attributed to street lighting, is a significant portion of public expenditure. Thus, there is a need for increased awareness and education. Of all the pollutions created by man today, light pollution seems to be the easiest to rectify (Klinkenborg, 2008). There are opportunities to submit proposals for the inclusion of light pollution control in County Development Plans. Simple measures to minimise light pollution can be undertaken both in the public and private sector, as well as implementing sensible lighting installations that serve their purpose efficiently.

This literature review has also shown that there is an increasing interest in the subject of astronomy. This could be an opportunity to promote education and awareness on the impact of light pollution. Many of the recognized Dark-sky parks and reserves in the UK already have educational material available to those interested in star-gazing. However, in most cases they are simply information brochures and there is scope for more expansive, educational programmes. The "Leave No Trace" Awareness campaigns are a good example of the environmental outreach programmes that can be incorporated into

education and something similar could be created to raise education on Light Pollution.

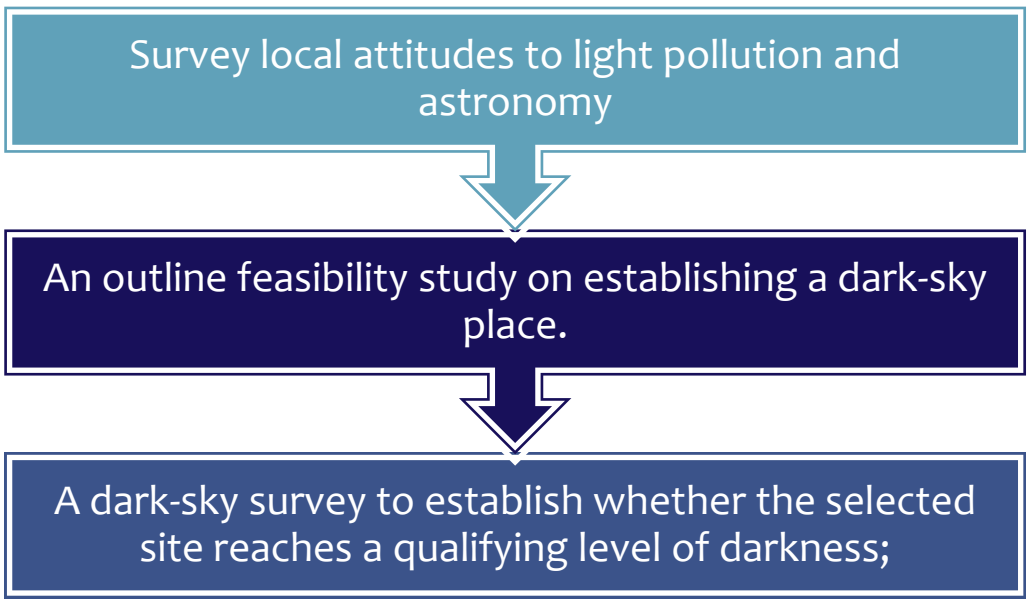
Within this chapter the subject of Dark-sky application and recognition has been mentioned repeatedly. Although the justification for establishing a Dark-sky place may put economic factors over environmental concerns, it is likely that introducing new locations for Dark-sky observation will enhance public awareness of light pollution. This could eventually lead to policy inclusion. During an Oireachtas Debate in April 2014, Deputy Leo Varadkar (Minister for Transport, Tourism and Sport) confirmed the Kerry International Dark-sky Reserve would be included by Tourism Ireland as "an important experience on the Wild Atlantic Way". This shows significant support at a senior level (Oireachtas Debates, 2014).

It is too soon to assess how significant this commercial exposure will be for Dark-sky preservation elsewhere. Nevertheless, it is a positive step and leads this literature review to conclude with a recommendation that other Dark-sky zones are pursued, not only for the tourism and leisure potential, but for environmental conservation, health, energy and educational benefits.

3. Methodology

3.1 Introduction

The study has focused on the impact of light pollution, leading to the value of preserving our night-time skies. A key component of this study was to examine the factors that led to the establishment of a formally recognised Dark-sky place. This determined a three stage approach to this study, using the following elements to conduct research;



The following sections outline and describe the methodology used. These sections include; the Research Design and Rationale; Survey Instruments, Dark-sky Survey, Data Collection Procedures, Outline Feasibility Study and Methodology Constraints.

During the timeline of this study, the choice of methodology evolved into a mixed-method approach, culminating with basic feasibility study. The reasoning

behind each approach is outlined in the section below entitled Research Design and Rationale.

3.2 Research Design and Rationale

In the course of research for this dissertation, a natural sequence of events occurred in understanding the subject matter, and this framed the shape of the survey instruments used to obtain both qualitative and quantitative data.

Establishing an awareness of light pollution was the first step taken in this process. It is important to note that this researcher has no astronomy background and has approached the subject of light pollution as a lay person. Understanding the impact of light pollution raised interest in how it could be minimised and this led to the consideration of Dark-sky places as a conservation concept.

Therefore, assessing local awareness of light pollution was a key factor in the decision to include an Awareness Questionnaire (see Appendix ii) in the research. The results of this would not only indicate the awareness of light pollution, but establish whether there is any demand for astronomy programmes.

In order to strengthen the results, the researcher decided to include an outline feasibility study to establish the practicality of establishing a Dark-sky place. The majority of themes examined in the feasibility study were drawn from the eligibility guidelines of the IDSA and the successful applications of existing Dark-sky places in the UK and Ireland.

Naturally, an application for Dark-sky status needs to feature a suitable site with qualifying data readings for sky quality (i.e. sufficiently dark). The next section looks at factors behind the selection of the Dark-sky site used in this study.

3.2.1 Site Description

Ballycroy National Park ("BCNP") was selected as the core study area. There were several reasons for this. Firstly, the site needed to be easily accessible to the researcher conducting the study from Newport and Castlebar in County Mayo. Comparable regions in the UK and elsewhere have utilised National Parks for core zones of Dark-sky Reserves and Dark-sky Parks, this is typically due to their management and sustainability, state-owned land, and ease of access for the public. The Kerry International Dark-sky Reserve ("Kerry Reserve") did not utilise a national park as its core zone, but it did encompass other protected sites such as the Skellig Islands (UNESCO World Heritage Site). The Kerry Reserve also made use of the geological topography, as the mountain ranges shield the reserve from the excesses of light pollution (Ormonde, 2013).

BCNP is situated in the Baronies of Burrishoole and Erris in north west Mayo. It is over 11,000 hectares in size and bordered to the south and east by the Nephin mountain range. The terrain is largely Atlantic blanket bog, and it is home to a diverse range of wildlife and natural habitats, many of which are Natura 2000 sites protected by the EU Habitats Directive. The landscape of this area is well known for its tranquility and remoteness. The 2011 census shows a population of less than 1,000 by selecting the entire land area within the N59 (national secondary route). Surrounding towns include Newport, Mulranny, Ballycroy,

Bangor and Bellacorrick. A large part of the National Park borders the Wild Nephin Wilderness park, which is owned and managed by the state forestry body, Coillte. The sky quality measurements taken in BCNP form the first baseline study for a dark-sky zone in County Mayo. This allows for scope to expand the core zone, with an extended "buffer zone", into a larger Park or Reserve when creating a formal application.

The park-owned boundaries are illustrated by the red outline in Figure 5. From this picture, it is easy to identify that some areas of the parkland are separated by publicly owned, or commonage land. This is a potential drawback for qualification as a Dark-sky Park (versus Reserve), and a decision will have to be made on the choice of application. This topic will be discussed later in the paper, in conjunction with IDSA advice received on the matter.

Figure 5: Ballycroy National Park boundaries

3.3 Survey Instruments

An Awareness Questionnaire and Unihedron Sky Quality Meters were the survey instruments chosen to obtain both qualitative and quantitative data for this research.

3.3.1 Survey Instrument; Questionnaire

The purpose of the questionnaire was to establish the public's level of awareness of light pollution in the towns surrounding the selected Dark-sky site, and to gauge the value applied to the night sky. It was not possible to find an existing questionnaire that was exactly suited, however, Dr Andrew Coogan of Maynooth University had designed a questionnaire for the purpose of assessing links between light levels in the environment and sleep patterns. With Dr. Coogan's permission, this formed the basis of the Awareness Questionnaire. The researcher then tailored the questions to complement the study's objectives. It was originally hoped that this instrument would assess the interest in the establishment of a local Dark-sky place. However, this required too much descriptive information. For example, a Dark-sky place would have to be clearly defined and explained to those unfamiliar with the term. The researcher was also concerned that such questions could be considered "leading" and affect the impartiality of the survey.

The final questionnaire contained eleven questions, most of which required multiple choice or Likert [2] scale responses. It begins by establishing the type of area the participant resides in before moving onto their opinions on lighting at

[2] *Likert scale; a rating scale to measure attitudes and strengths of opinion.*

night. The questionnaire asks the participants' opinion on the effects of excessive lighting on number of socio-environmental factors. Finally, the questionnaire seeks the participants' interest in astronomy and whether they consider their area to be suitable for recreational astronomy. A sample of the Awareness Questionnaire is attached in Appendix iii.

3.3.1.1 Pilot Survey

A pilot survey was deemed necessary to ensure the understanding of the questions in the Awareness Questionnaire. The main reason for this was due to the fact that it had not been used in a previous research project. Four pilot questionnaires were distributed to participants attending GMIT Castlebar Campus, but unknown to the author to maintain integrity. All four pilot surveys were fully completed, without question or difficulty for the participants. On this basis, the questionnaire was deemed acceptable, finalised and distributed to the sample groups mentioned above.

3.3.1.2 Distribution of Questionnaire

A total of seventy questionnaires were distributed via the following channels:

- Twenty questionnaires were distributed to a group attending a talk on light pollution held at GMIT, Castlebar Campus.
- Twenty questionnaires were distributed and collected by the Mulranny environmental officer.
- Twenty questionnaires were distributed and collected by the Ballycroy Community Centre Employment Officer.

- Ten questionnaires were sent to Newport residents by the researcher via a neighbourhood watch e-mail distribution list.

It was originally hoped that additional surveys would be taken in person outside local supermarkets in the towns surrounding Ballycroy National Park. However, time did not allow for this to be undertaken.

3.3.1.3 Questionnaire Data Integrity

In order to maintain data integrity, local community and environmental officers and fellow students were involved in distributing and collecting the questionnaires.

As mentioned above, twenty questionnaires were distributed at a lecture presented by Prof. Brian Espey on the topic of Light Pollution, held at the GMIT Castlebar Campus. It is noted that attendees at this event are likely to have at least some awareness of light pollution, although they were asked to complete and return the questionnaires prior to the start of the lecture.

3.3.2 Survey Instrument; Unihedron Sky Quality Meters

The study used a total of six Sky Quality Meters ("SQMs") manufactured and distributed by Unihedron in Canada. These meters measure how much light strikes their lens, or sensor, and converts that amount of light into a reading known as Magnitudes per Square Arc Second ("mpsas"). This term is defined in the abbreviations section of this document. All six SQMs were loaned, for the

purpose of this study, by Prof. Brian Espey of Trinity College Dublin's Astro-physics Department. These instruments recorded the quantitative data for this research.

Four of the meters were SQM-LU-DL models (See Appendix ii), affixed to wooden posts in selected locations, inside a weather-proof casing, together with a battery pack (6 x AA batteries) for the duration of their recording period. The fixed locations surrounding BCNP are illustrated in Figure 16. This shows that posts were installed at a total of six sites to allow additional data collections. These meters were pre-set to take readings at five minute intervals, starting from dusk until dawn.

The remaining two meters were handheld SQM-L models and were used to take manual readings. Instructions for taking these manual readings are simple and detailed on the IDSA website. Essentially, the device is pointed overhead (at the zenith), and a button pressed to trigger a reading. Within a few seconds the digital display gives an indication of the darkness of the night-sky above, compared to the darkest possible place (i.e. pitch black). The meters have been pre-calibrated with a darkest possible reading so they are ready to make this comparison.

There is a considerable amount of technical information pertaining to how SQMs work and the calculations of Mpsas. For the purpose of this study, it was not deemed necessary to go to this detail. The reader can find more information on the websites of both Unihedron and the IDSA.

3.4 The Dark-sky Survey

The methodology for conducting a night sky quality survey was developed for this study in consultation with Prof. Espey, and with the assistance of the NPWS Park Rangers. Time constraints were taken into account to acquire the maximum number of readings from key locations. To ensure a comprehensive survey, SQM readings must be taken at both the darkest and the brightest areas of the zone.

The fixed meters were installed on 14th February 2015 at four data collection points, which were safe to access and appropriately distributed.

The general guidelines for taking SQM readings are listed below (Owens, 2012)

- Away from light sources or anything that may block the night sky (or in an area shaded by trees or buildings).
- At least 4-6 readings per location should be taken with the results averaged (this applies to handheld SQM-L Models).
- Take readings on clear, moonless nights to ensure the natural darkness of the location is not distorted by the moonlight.
- The meter must be pointing at the zenith (i.e. directly overhead).
- Note the reading and number produced by the SQM. The higher the number, the darker the sky above.

The combination of fixed and handheld meters used in this methodology to record data over extended periods, exceeds these requirements.

In selecting a usable method for this study, a review of other methodologies presented in Dark-sky application forms was conducted. The most notable

difference was in the SQM models used. For this research, the majority of readings were taking on a continuous basis from fixed positions. This allows for analysis during changing weather conditions and lunar cycle periods. A snapshot of this data has been used for the purpose of this dissertation, however, data collected over an extended period will be used for the final Dark-sky application. Recent communications with the IDSA confirmed that this is not only an acceptable method, but further stated that they "usually receive SQM data from only a handful of nights, which increases the likelihood of not measuring a truly random sample." The IDSA is considering the introduction of a minimum period over which readings must be taken (J Barentine 2015, pers. Comm, 17 Mar).

Another significant difference in methodology is the number of locations from which readings have been taken. Typically, Dark-sky applications would survey a minimum of twelve locations at cross-sections in the selected site. Due to equipment and time limitations, this study has covered five fixed locations with continuous data from the SQM-LU-DL meters, plus a number of random position readings taken with the handheld meters.

The next section will discuss the data collection procedures for the Dark-sky survey.

3.4.1 Data Collection Procedures

As discussed in the previous section, the Unihedron SQM LU-DL meters record data every five minutes of every night from dusk-to-dawn. Therefore, they accumulate a vast number of data records in a short space of time and require

regular retrieval. The researcher collected the data for this study by connecting the SQM Meter to a laptop, extracting the records using software downloaded from Unihedron, and converting this file into Excel format. The records on the SQM were then erased to make space for more continuous readings.

Data captured by the two handheld SQM meters was manually recorded into a spreadsheet, including date and time, grid reference/co-ordinates, weather conditions and temperature. Five to six readings were taken at each location.

This brings the survey and data collection of the methodology for this study to a close. The next section looks at the structure of the outline feasibility study used to assess the suitability of BCNP as a candidate for Dark-sky status.

3.5 Outline Feasibility Study

A major factor in the feasibility study for this project is to evaluate whether the site would successfully qualify for Dark-sky recognition. Establishing the level of darkness has been covered in the Dark-sky Survey section, but this is not the only criterion required for qualification. The successful application submissions of Dark-sky sites in the UK and Ireland were reviewed to identify the critical components that should be considered in this feasibility study.

Each Dark-sky application is typically in excess of one hundred pages, and therefore only a snapshot of the requirements will be provided in this study. The content selected for inclusion has been drawn from communications with each of the Dark-sky Parks and Reserves to identify the most significant themes. Details of the contributing parties are listed in Table 1. The responses received

from have been collated into recurring themes, which form the basis of the feasibility study headings, rather than a standard business research template. This information will be presented in summary format in the results chapter.

Table 1: Comparable Dark-sky Places

Name of Applicant	Type of designation Award & Date	Contact Person (Title if known)	Communication method and date
The Brecon Beacons National Park, South Wales	Dark-sky Reserve Silver Tier 2013	Ruth Coulthard Brecon Beacons National Park Authority.	Phone conversation 26th January 2015 & various email communications
Northumberland National Park and Kielder Water and Forest Park, Northumberland, UK	Dark-sky Park – Gold Tier 2013	Duncan Wise Visitor Development Officer, Northumberland National Park	Phone conversation 26th January 2015 & various email communications
Kerry Dark-sky Group, Waterville, Co. Kerry	Dark-sky Reserve Gold Tier 2014	Julie Ormonde Project Manager Kerry International Dark-sky Reserve	Phone conversation 22nd January 2015 & various email communications
Galloway Forest District, Wigtownshire, Scotland	Dark-sky Park Gold Tier 2009	, Muir Head of Tourism, Galloway Forest District	Email communications 11th – 19th January 2015
Exmoor National Park Authority, UK	Dark-sky Reserve Silver Tier 2011	Sarah Bryan/Dan James – Conservation & Sustainable Economy Exmoor National	Email communications 14th January – 12th March 2015

3.6 Methodology Constraints

It was initially envisaged that access to equipment would form the main problem in conducting a Dark-sky survey. However, this has been addressed by the goodwill of Prof. Espey in lending the equipment for this study.

Regular co-operation was required from the National Parks and Wildlife Service in Ballycroy to approve the site planning and installation of fixed posts for the SQM meters. Regular access to the grounds at night-time was permitted.

The distance between the meter posts required the survey work to be conducted by car. This meant covering a minimum of fifty kilometers per site visit and, in some areas, a walk-in on unforgiving terrain. Appropriate weatherproof clothing and boots are a dress-code "must" for the completion of this survey! A typical visit to retrieve data from the data collection points takes approximately five to six hours. In the Appendices, the researcher has included a sample of the activity log showing visits to the SQM locations to retrieve data. Some of the issues faced in collecting data are also noted in this log.

3.7 Conclusion

This chapter has described the mixed-methodology approach taken in this study. It has discussed the rationale behind the selection of the survey instruments, and the design of the Outline Feasibility Study. If this study should lead to the submission of an application for Dark-sky status, it is anticipated that the methodology established could be utilised for additional survey work, and the framework for a draft Dark-sky application submission.

Having established a methodology for this study, the next chapter now turns attention to the results found.

4. Results

4.1 Introduction

This chapter presents the results of the research. The first section deals with the results of the Awareness Survey, whilst the following sections present the results of the Dark-sky Survey and the Outline Feasibility Study. The quantitative data generated from the Awareness Survey and Sky Quality Survey is presented in chart and table format. The results section of the Outline Feasibility Study has been compiled in descriptive format, using a thematic approach.

4.2 Awareness Survey

As discussed in the Methodology Chapter, the Awareness Survey consisted of an eleven-point questionnaire. A total of forty-nine questionnaires were returned to the researcher, out of the possible seventy. The responses were transposed into Excel and interpreted with the aid of charts prepared by the researcher. The following results are presented in three thematic sections; Participant Profile, Awareness of Light Pollution, Interest in Astronomy. As far as possible, the researcher has followed the sequence of the questionnaire for the reader's convenience.

4.2.1 Participant Profile

The participants were asked to describe the area in which they live by selecting from a multiple choice. The choices offered were Rural; Village; Small town; Medium town. They were also asked to name their nearest town. In addition,

the participants were asked to gave an indication of the type of external lighting, if any, they have on their residence.

The results from these questions give the researcher an indication of what level of LAN the participant might usually experience.

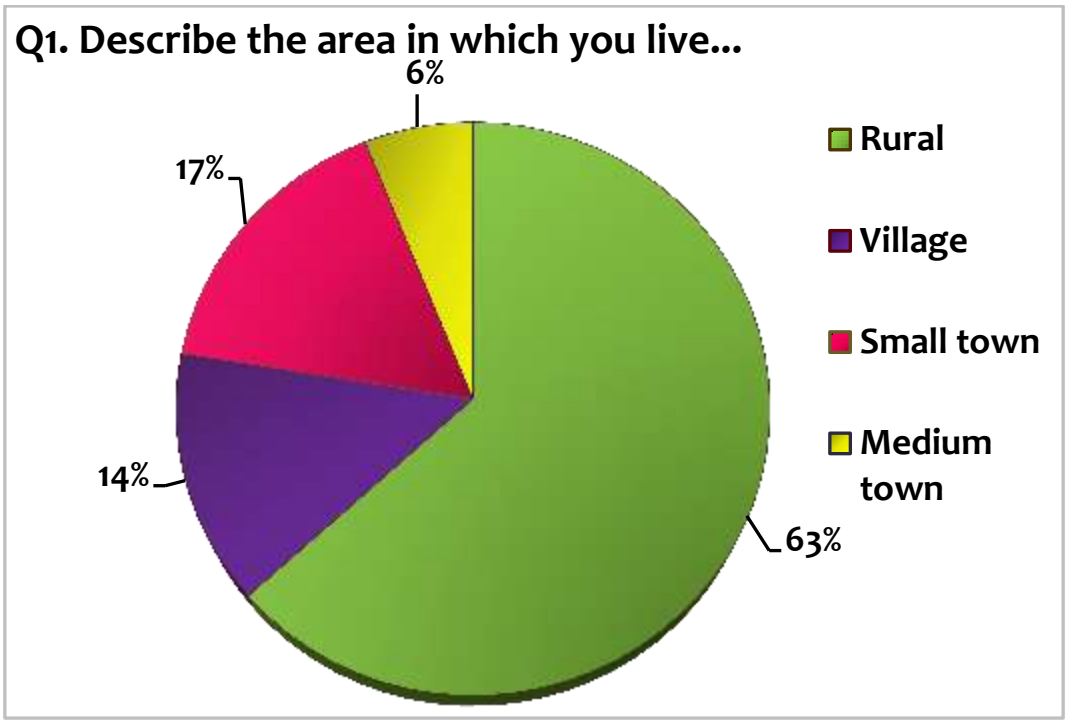


Figure 6: Question 1 - Establishing the Area of Residence

The main information the researcher noted from the chart in Figure 6, was that 63% of the participants in the survey considered their area to be rural. Therefore, it is unlikely that their area is exposed to a significant level of lighting at night.

The researcher has shaded three segments in the bar chart in Figure 7; to highlight that Bangor, Mulranny and Newport are the periphery towns of Ballycroy National Park.

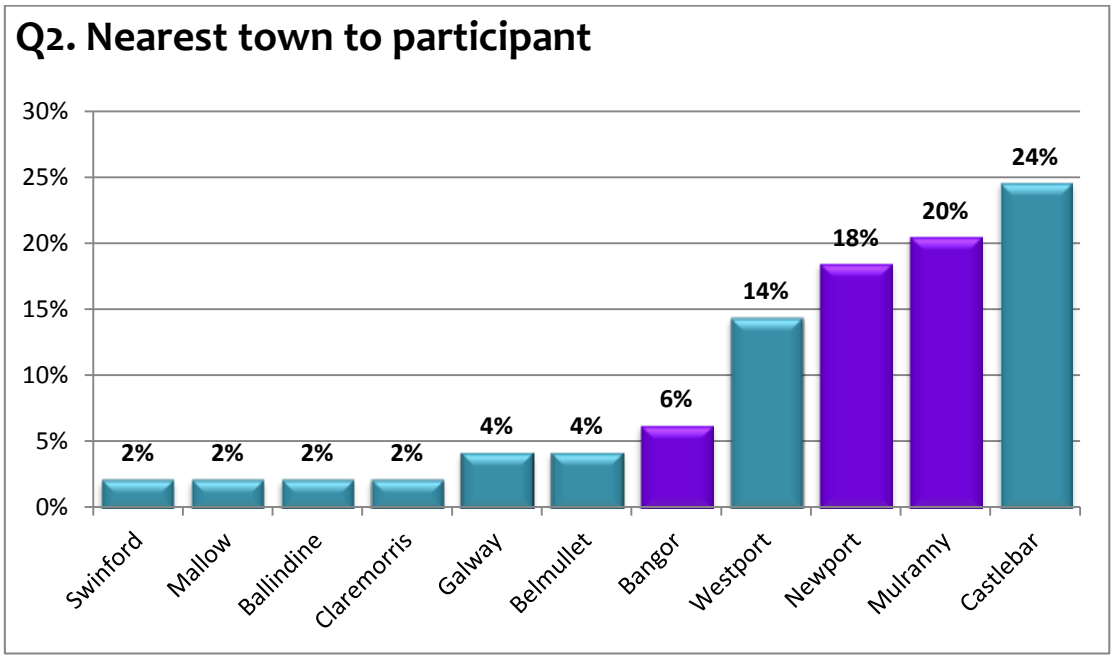


Figure 7: Question 2- What is your nearest town?

The next chart displays the participants' opinions on how bright their residence is at night-time.

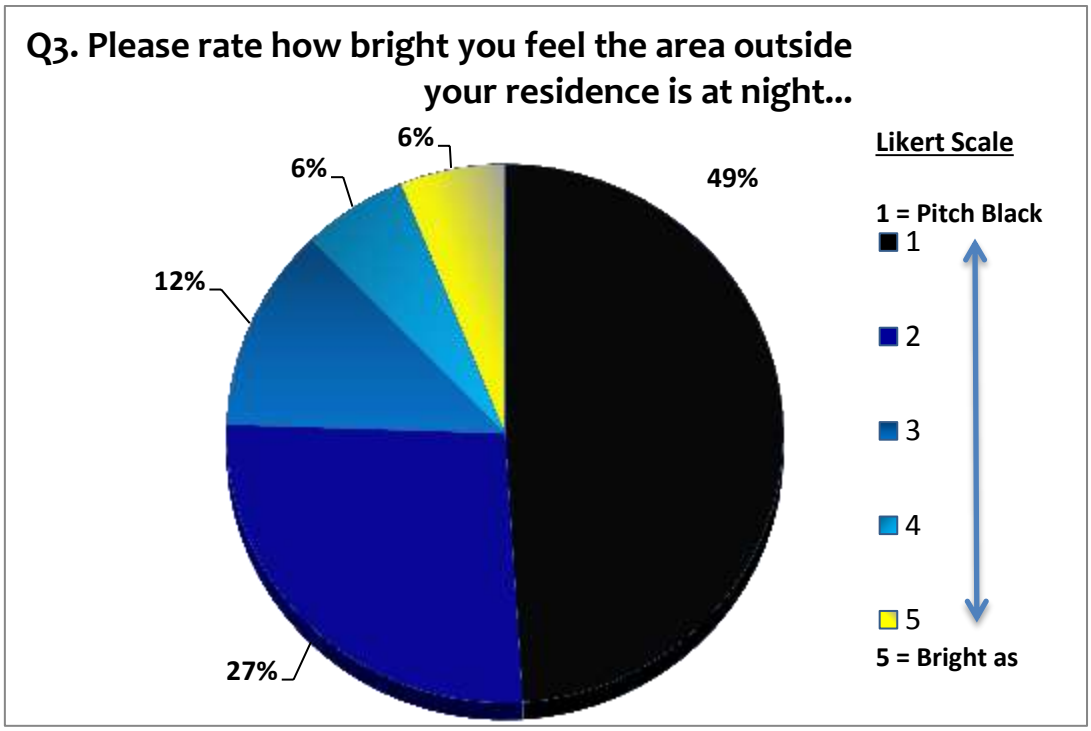


Figure 8 Q3: How bright is the area outside your residence at night?

The information presented in the chart in Figure 8 indicates that almost half of the participants considered the night skies on their doorstep to be pitch black i.e. unpolluted. It is worth noting that the 6% who considered their residence to be "Bright as Day" hailed from the towns of Newport, Castlebar and Swinford.

The bar chart in Figure 9 shows the percentage of participants who have fitted external lighting to their property, of various types. The most significant aspect of this chart is that over 78% of people have external house lights. Whilst this figure was not unexpected, it provides a reminder that domestic lighting is widespread. Therefore, it is a potential source of local light pollution if poorly directed, or if excessive for the task required.

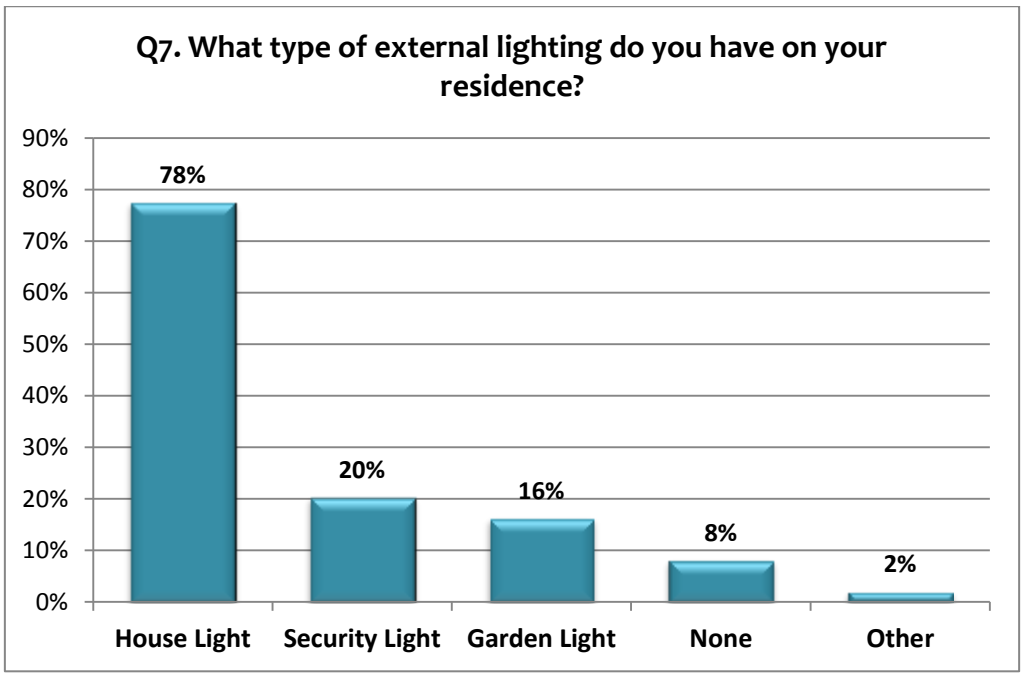


Figure 9: Q7 - Type of external lighting on Participants' residence

4.2.2 Participants Awareness of Light Pollution

This is the first of the multi-part questions using a Likert scale. The data presented in the following chart illustrates the sources of light pollution that the participants may have noticed in their locality.

Representing this data clearly required experimenting with several chart formats. The eventual chart selected displays an average of the results for each of the sources of light mentioned in the question (see Figure 10). This was not an ideal choice of representation, but it does give the reader an "at a glance overview" of the responses.

The researcher examined the actual survey data with a standard deviation[3] and found that the widest range of responses occurred in the question on street lighting. Some respondents considered street lighting in their area to be "highly excessive" (rated 5), whereas others considered its effect to be "none whatsoever" (rated 1). Unsurprisingly, these views aligned the excessive street lighting opinions with those living in a town, and those with zero effect were living in rural areas.

[3] *Standard deviation; a measure of how spread out the data is compared to the average*

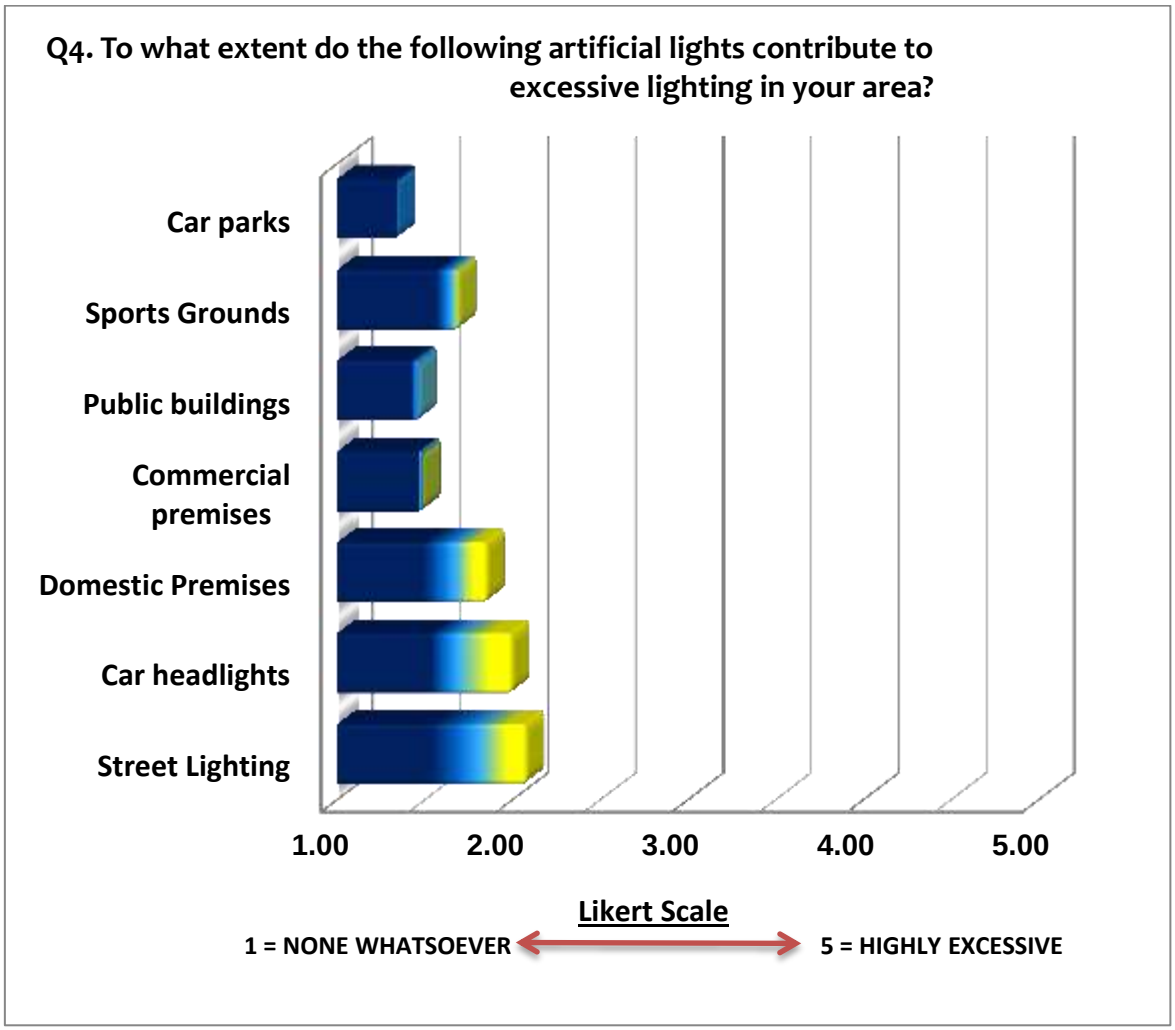


Figure 10: Q4 - Excessive lighting in your area

The data presented in the following chart (Figure 11) illustrates the participants' awareness of the effect of street lighting on a number of environmental and social factors. The results have been presented in the same format as Figure 10, using an average rating of the participants' responses for each category.

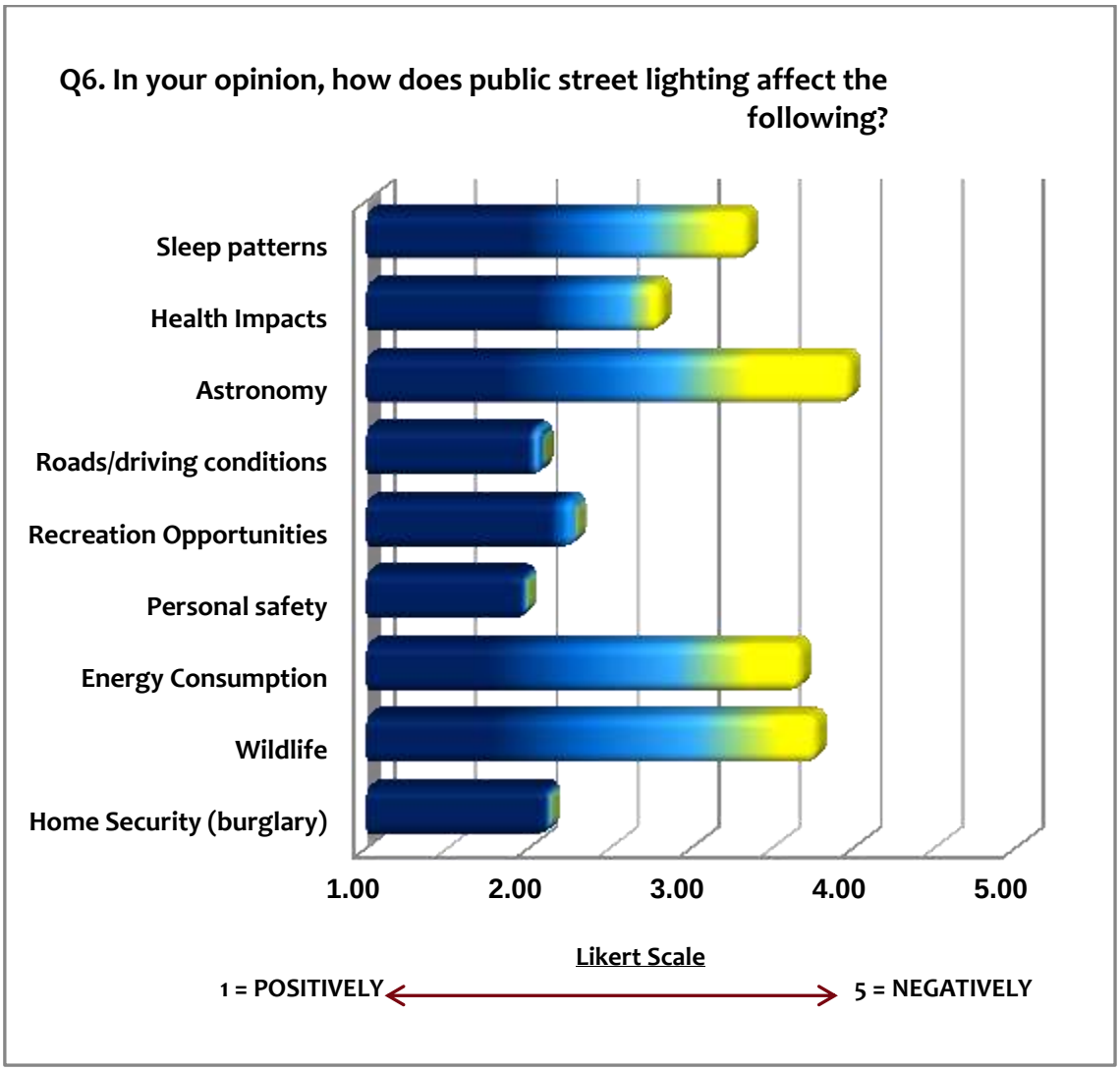


Figure 11: Q6 - The effect of Public Street Lighting

The questionnaire also asked the participants to provide descriptive answers on what they consider to be the main source(s) of night-time illumination in their area. As this data was largely free-flow, descriptive text, the researcher has grouped the most repetitive answers by frequency in the chart in Figure 12:

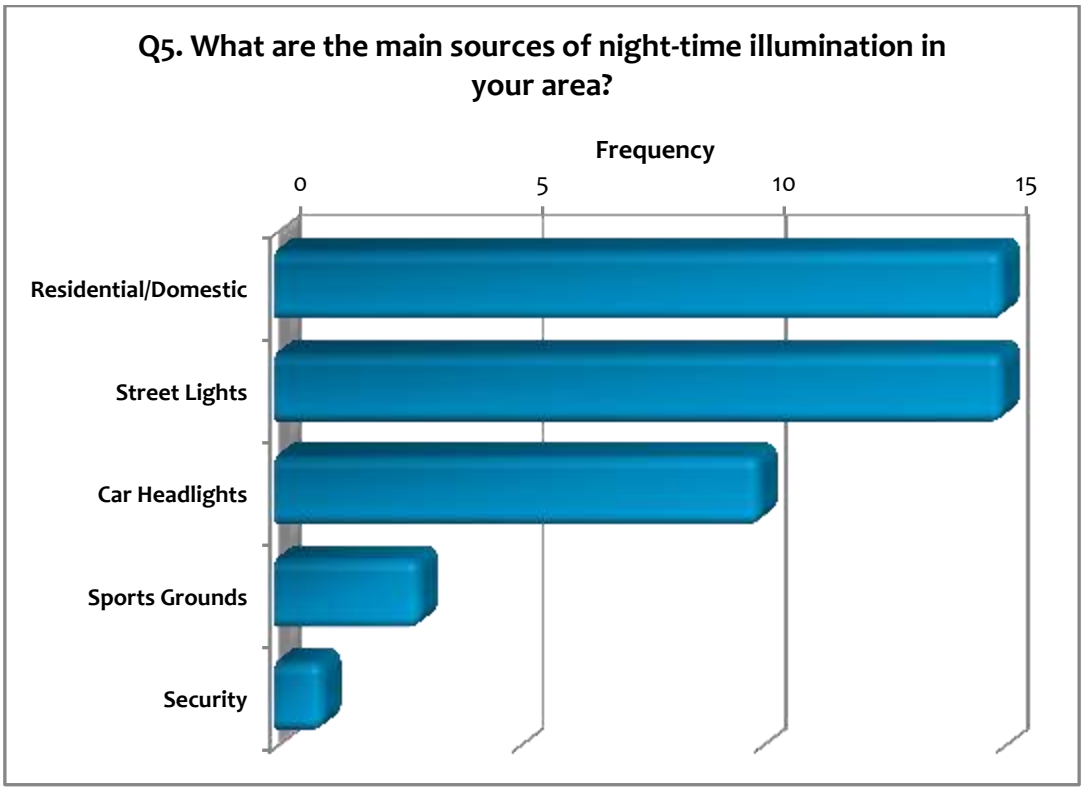


Figure 12: Q5 - Main sources of night-time lighting

The participants' responses to this question indicate that, in their opinion, residential lighting and public street lighting are jointly the most significant sources of night time illumination in their area. Given that the profile of the participant is largely rural, it is understandable that the most noticeable lighting at night comes from domestic sources on neighbouring houses. Home security lighting featured quite low in the frequency of response. It is possible that the descriptive nature of the answer required, could have resulted in participants assigning residential lighting and security lighting into one phrase. Thus distorting the result for domestic lighting.

4.2.3 Participants' Interest in Astronomy

The final section of the Awareness Survey presents results relating to the participants' interest in astronomy.

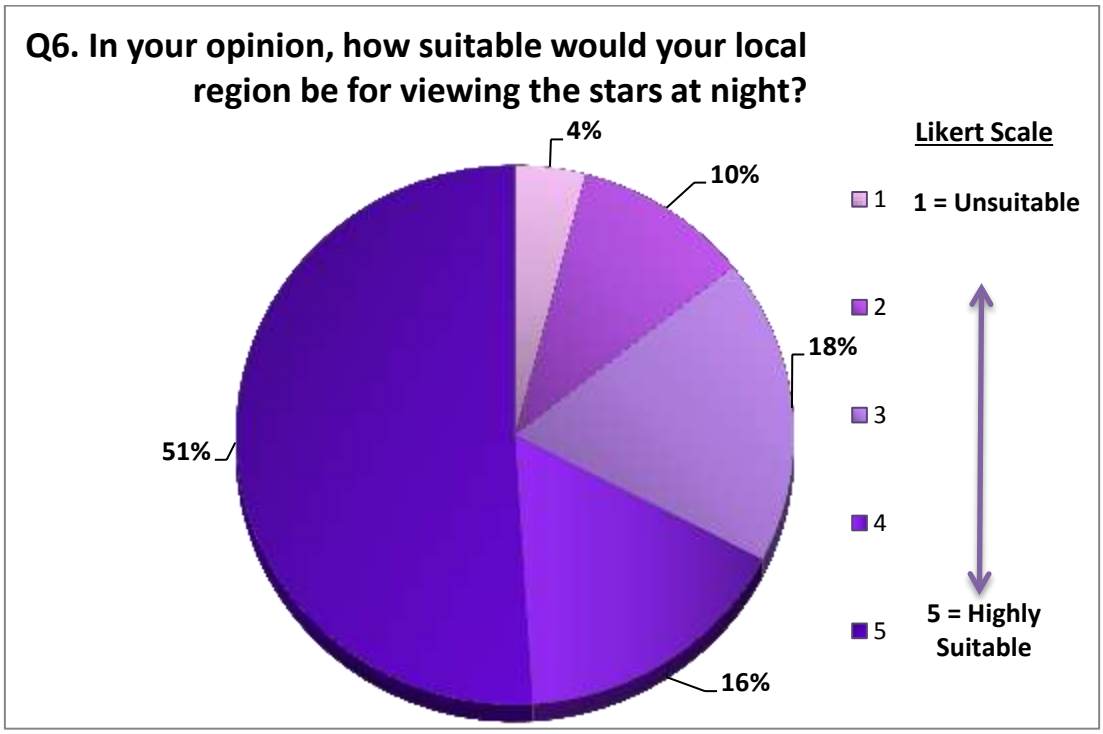


Figure 13: Q6 - Participants' opinion on quality of their area for astronomy

It is clear from the results presented in Figure 13, that 51% of the participants considered their area to be highly suitable for astronomy. This correlates well to the information contained in Figure 8, where 49% of participants indicated the area outside their residence was "pitch black" at night.

This leads to the penultimate question in the survey and the last chart (Figure 14). Participants were asked how often they would appreciate the night-time skies, in an effort to understanding their potential interest in astronomy.

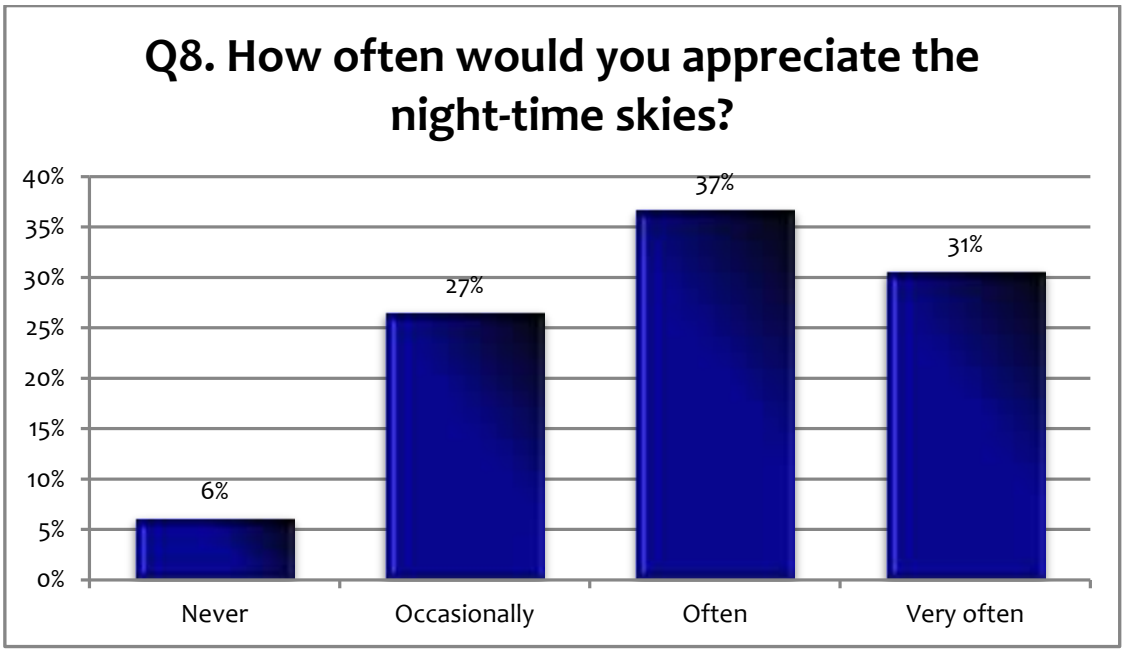


Figure 14: Q8 - Frequency of observing the night skies

The responses indicated that 94% of the participants have some appreciation for the night skies. The bar chart represents how frequently, they might take the time to observe the stars at night. Only 6% of those surveyed would never take time to appreciate the night skies.

The final question in the Awareness Survey, asked participants whether they would be interested in local astronomy programmes, if they were available. The question was structured as a simple YES/NO response. The results were 96% "YES", and 4% "NO". This is a very positive indication of the level of interest in astronomy within the Mayo region.

4.2.4 Summary of the Awareness Survey

The results presented from the Awareness Survey data were taken from forty-nine responses. The majority of these were in rural locations, where communities do not consider lighting to be excessive. However, it is clear that residential lighting is important to many people. This is relevant to information included in the Literature Review chapter where Dr. Kate Painter comments that rural lighting may highlight a crime more than in the urban centre (Clover, 2010).

The general awareness of light pollution and its impact is low, particularly in relation to health matters, underpinning the justification for this paper. This point will be reviewed in the following Discussion Chapter.

Finally, the results from the Awareness Survey give a very positive indication of the interest that the community has in local astronomy. Although the participants were not specifically surveyed about dark-sky zone development, their interest in astronomy programmes indicate that they are they are likely to support its concept.

This leads to the presentation of the results for the technical and quantitative aspect of this research; the Dark-sky Survey.

4.3 The Dark-sky Survey

The data retrieved from the fixed place meter positions around the Ballycroy National Park has returned positive results. However, the volume of readings, from multiple locations, makes interpretation somewhat cumbersome. In order to put the information into perspective, Table 2 shows the qualifying classifications sought by the IDSA for a Dark-sky status award. Depending upon the level of darkness measured in the survey, the Dark-sky place can be classified as Bronze, Silver or Gold.

Table 2: IDSA Classification tiers for SQM readings

Classification Tier	Unihedron Sky Quality Meter Readings of Magnitudes per sq. arc second (mpsas)
Bronze	Greater than 20, Less than 21
Silver	In excess of 21 and less than 21.7
Gold	In excess of 21.7

For the reader's convenience, an overview of SQM readings is presented in Figure 15. These readings have been grouped by frequency and allocated in the classification tiers provided above. Only one location has been provided in this sample to reduce repetitiveness. Suffice it to say, meter readings in all locations recorded qualifying data, some more frequently than others.

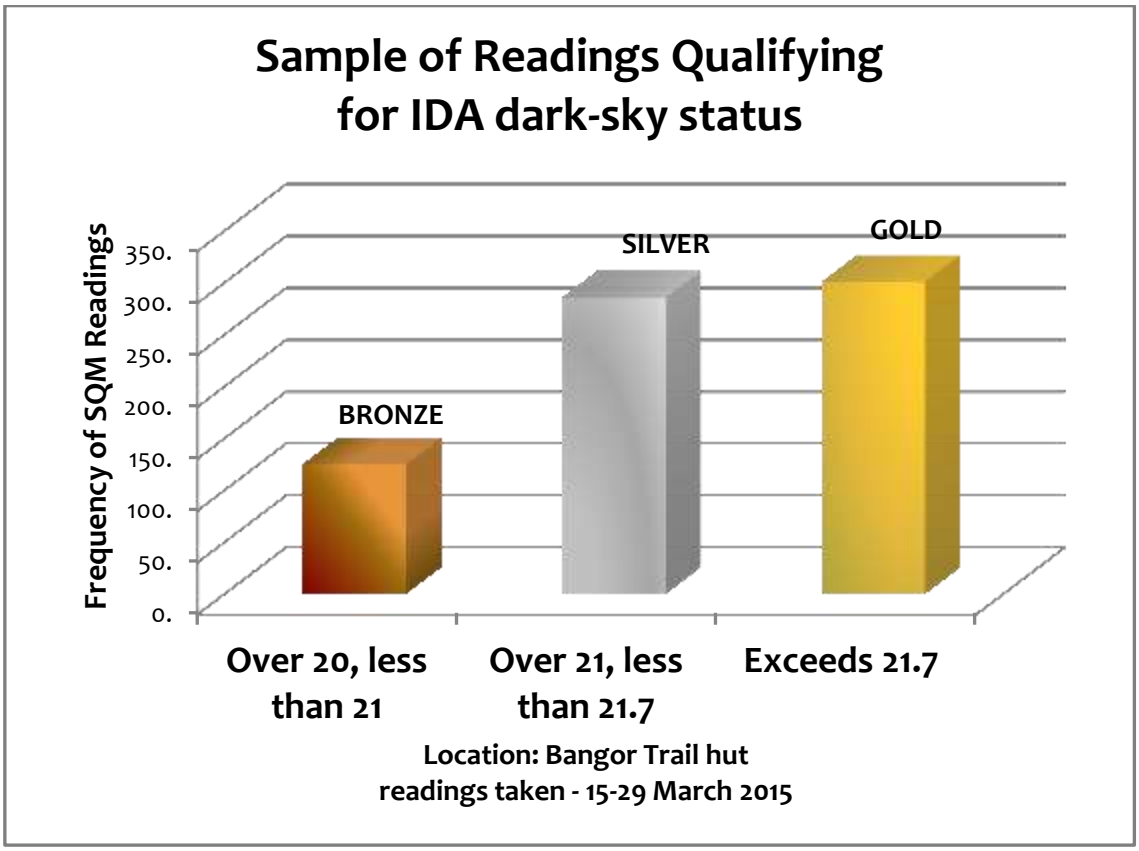


Figure 15: SQM Readings classified in IDA tiers

4.3.1 SQM Findings

The researcher obtained data readings from five separate locations by moving the meters around, and this accounts for some gaps in the date ranges. All locations are marked on the map of the area provided in Figure 16.

This map is followed by a series of scatter charts presenting data from meters in each location. These meters took continuous readings, and the nightly cycles can be seen from the peaks and troughs of the charts, as light changes from night to day. The charts presented herein have been edited for the reader's convenience to highlight the qualifying range of readings for Dark-sky application.

Results from Dark-sky Survey Readings:

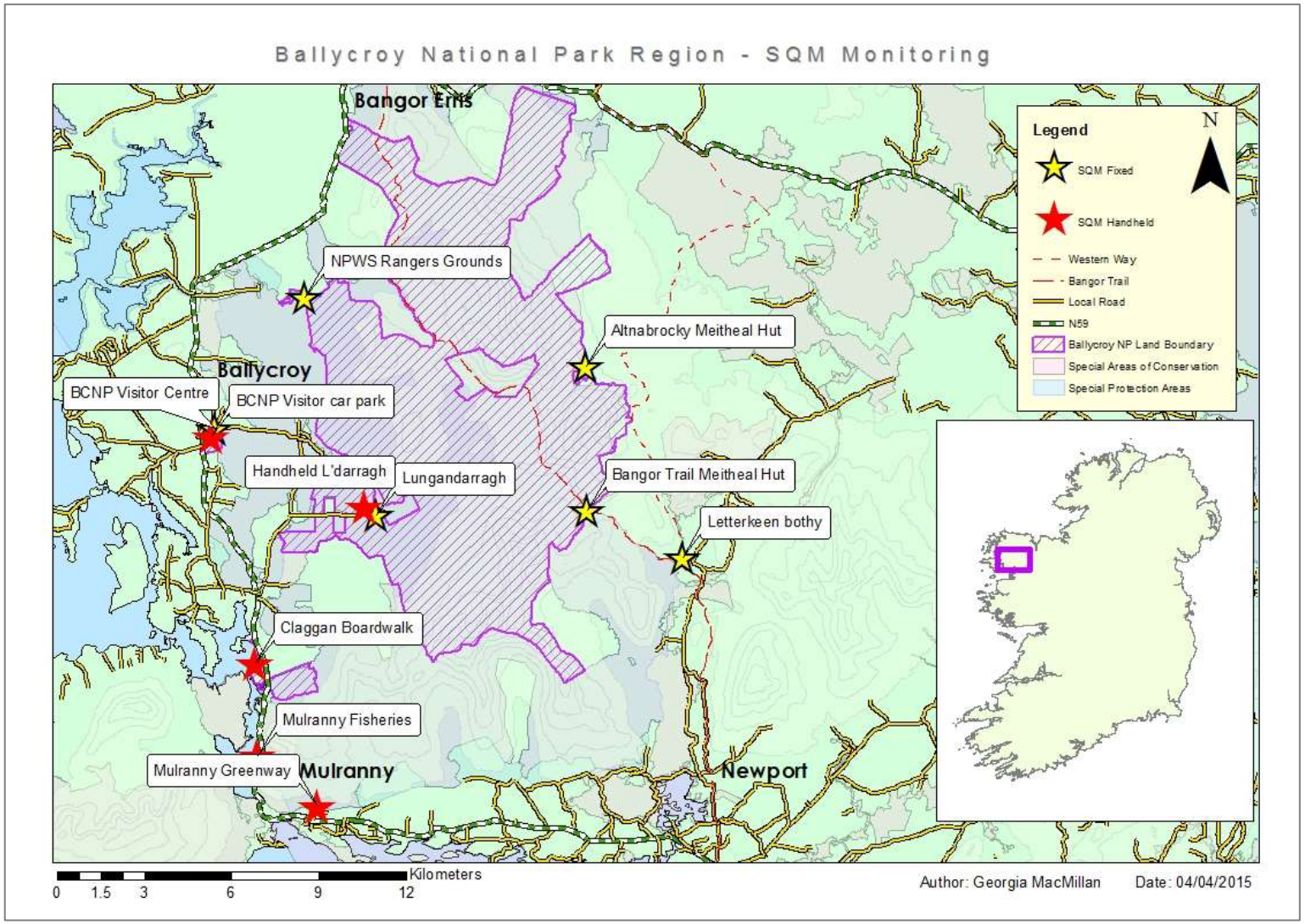


Figure 16: Dark-sky Survey - SQM Locations

Results from Dark-sky Survey Readings:

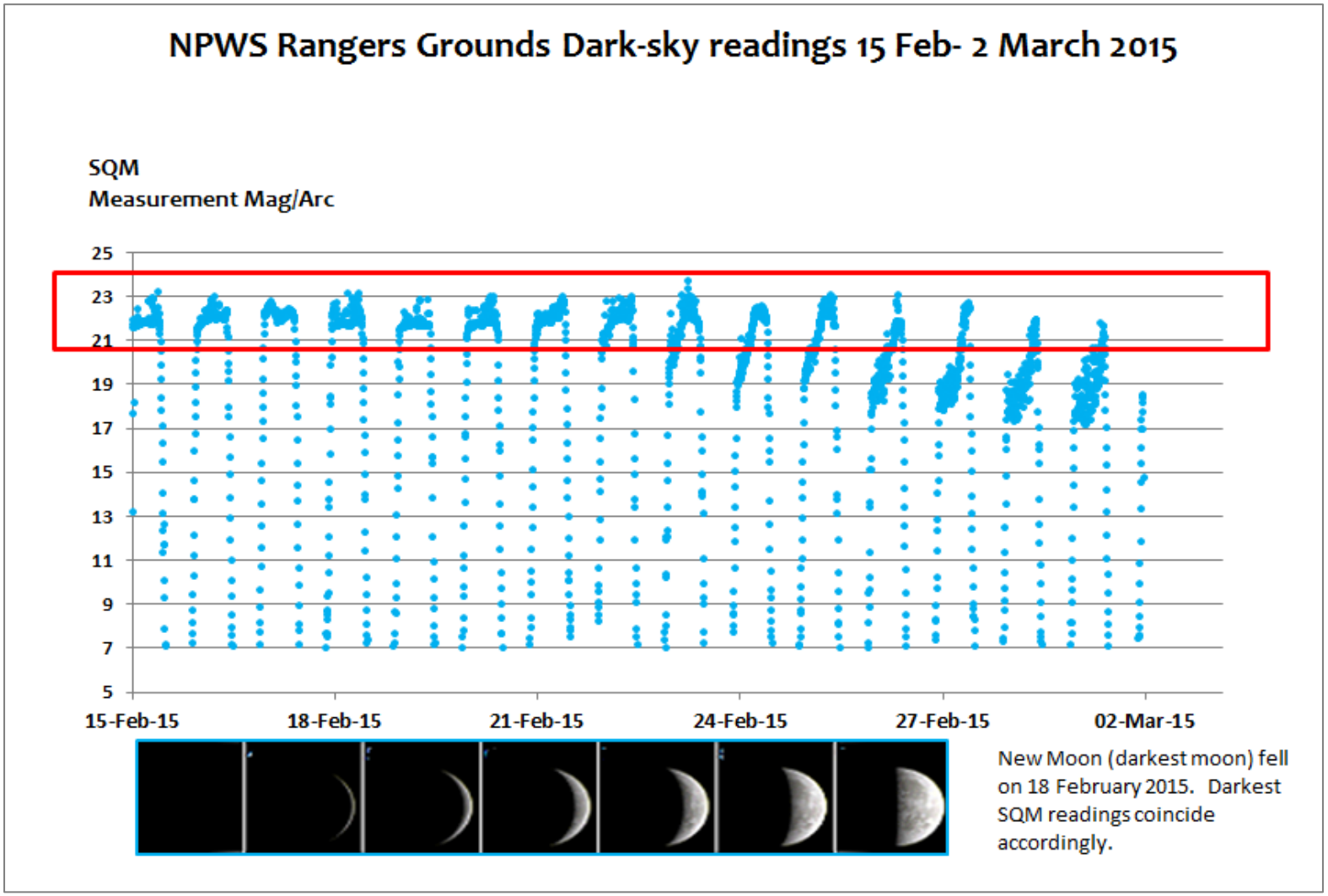


Figure 17: Rangers Office SQM readings 15 Feb to 2nd March

Results from Dark-sky Survey Readings:

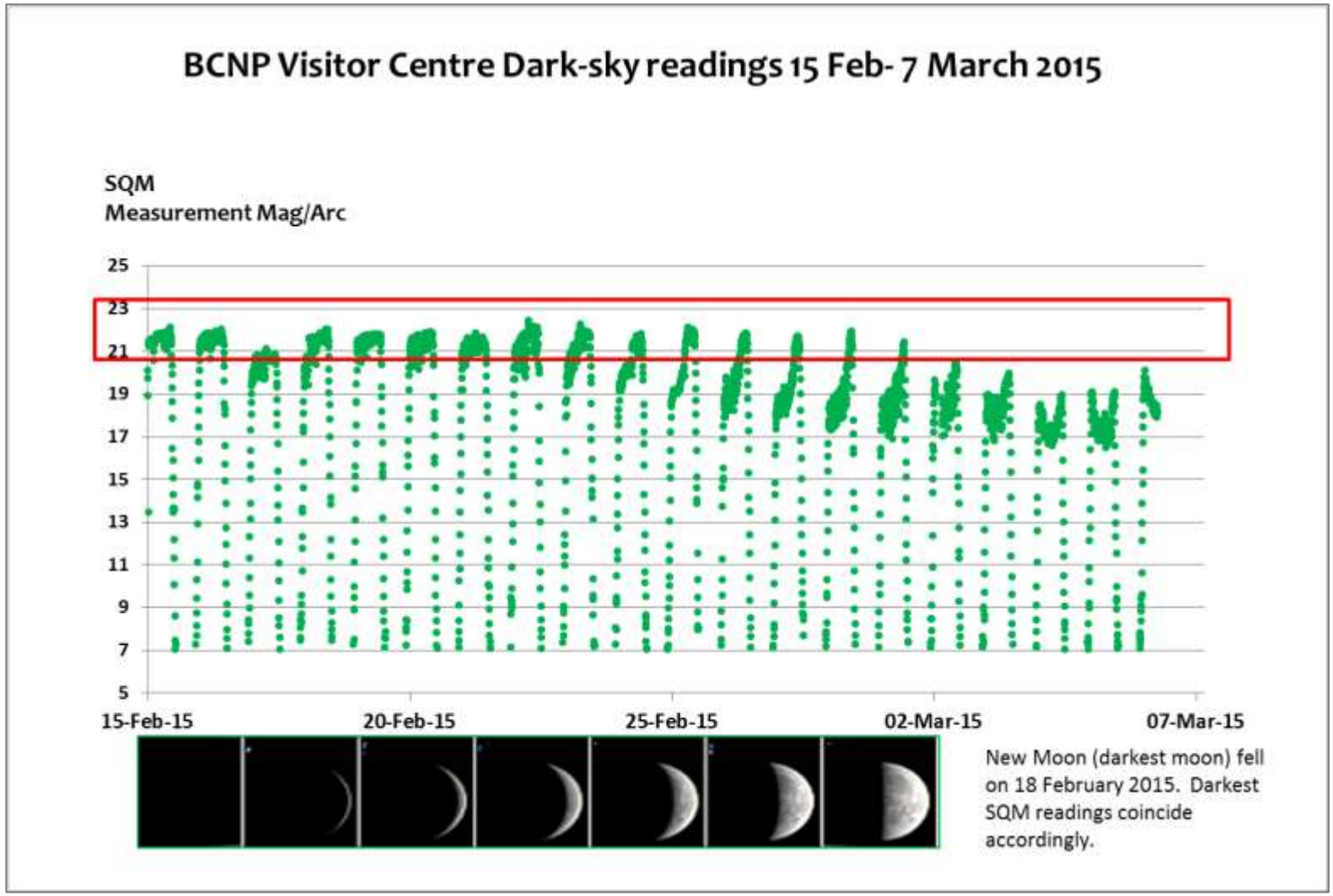


Figure 18: BCNP Visitor Centre SQM readings 15 Feb - 7 Mar 2015

Results from Dark-sky Survey Readings:

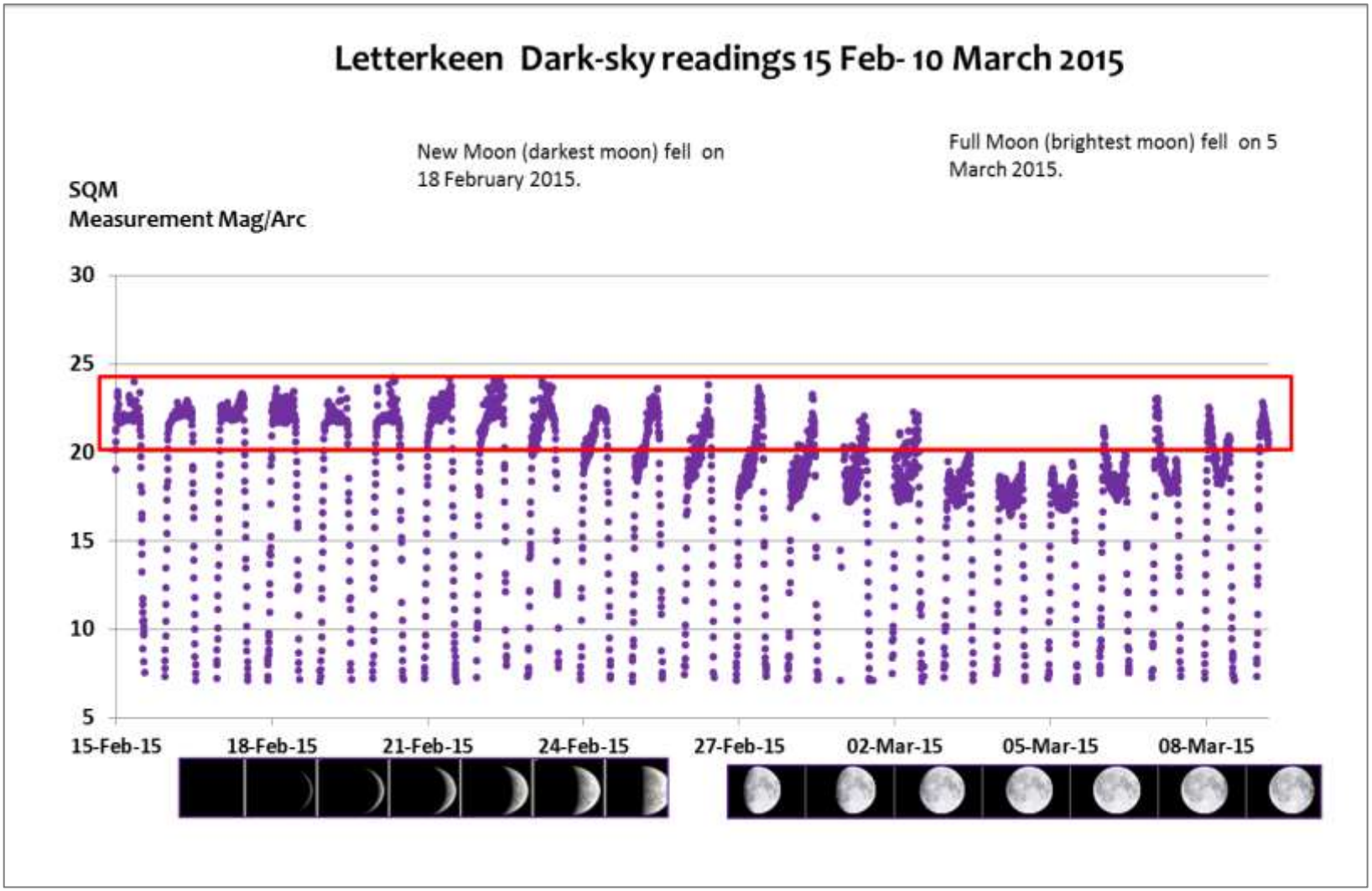


Figure 19: Letterkeen SQM Readings 15 Feb-1 Mar 2015

Results from Dark-sky Survey Readings:

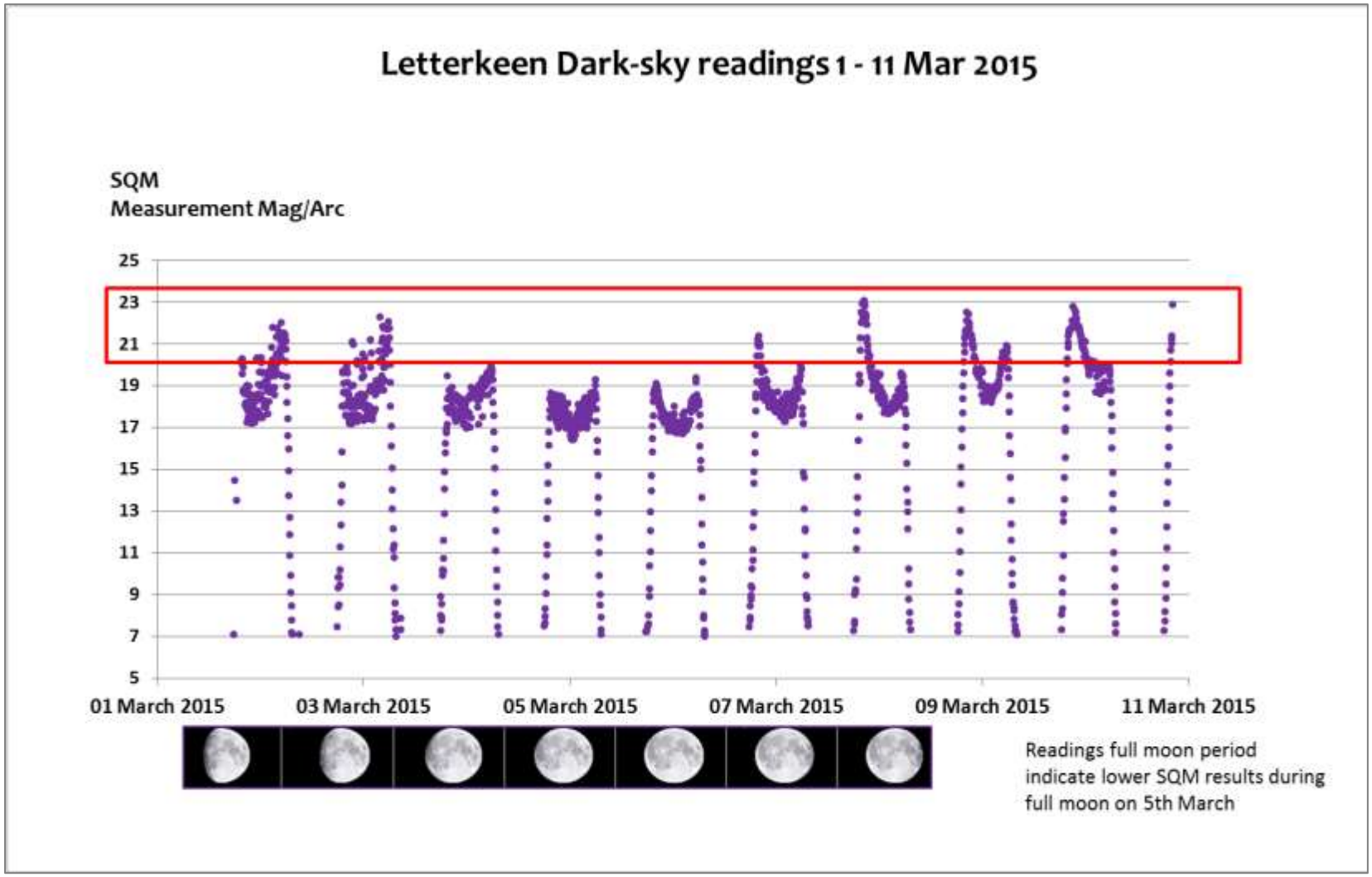


Figure 20: Letterkeen SQM readings 1-11 March 2015

Results from Dark-sky Survey Readings:

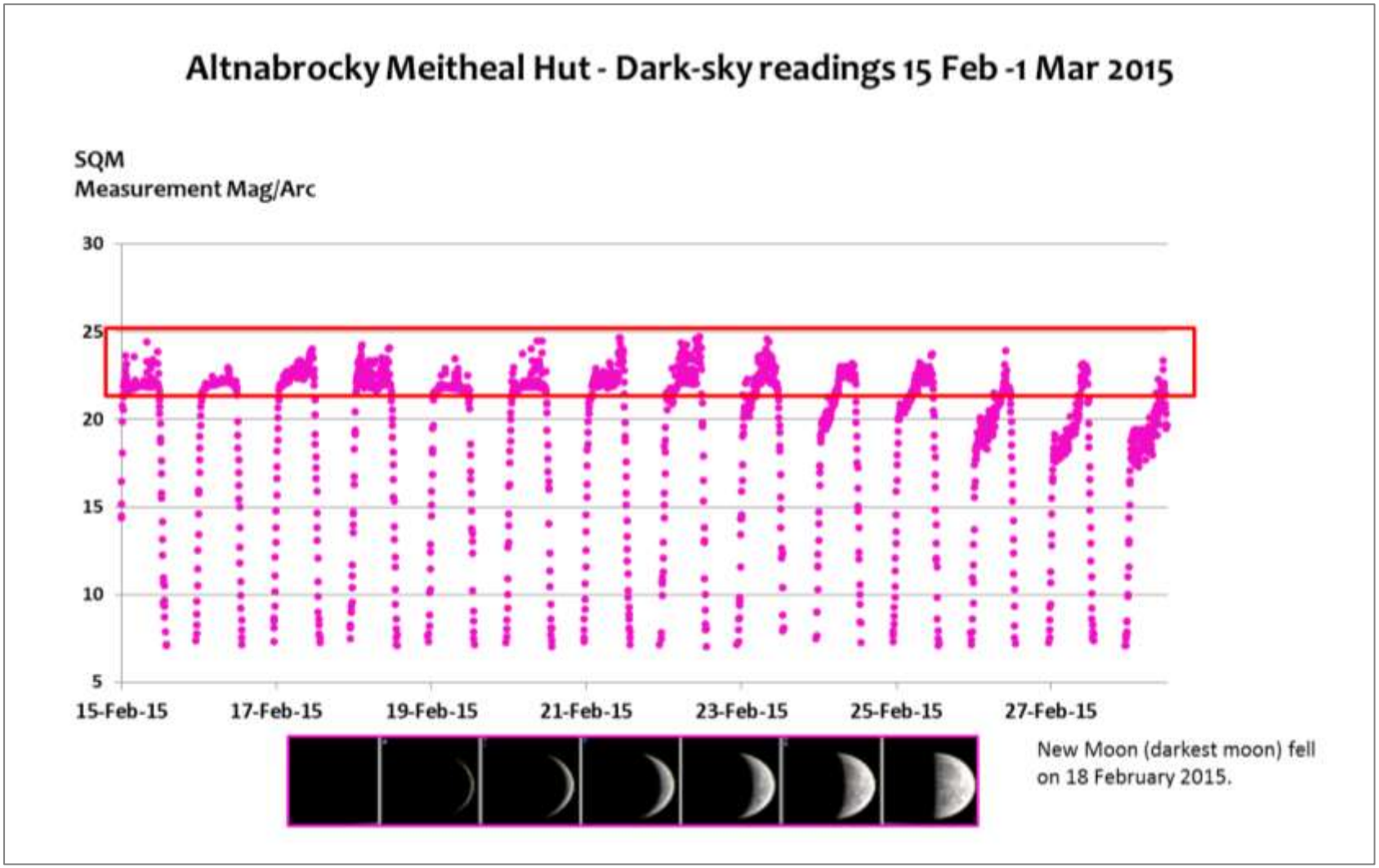


Figure 21: Altnabrocky Hut SQM readings 15 Feb-1 Mar 2015

Results from Dark-sky Survey Readings:

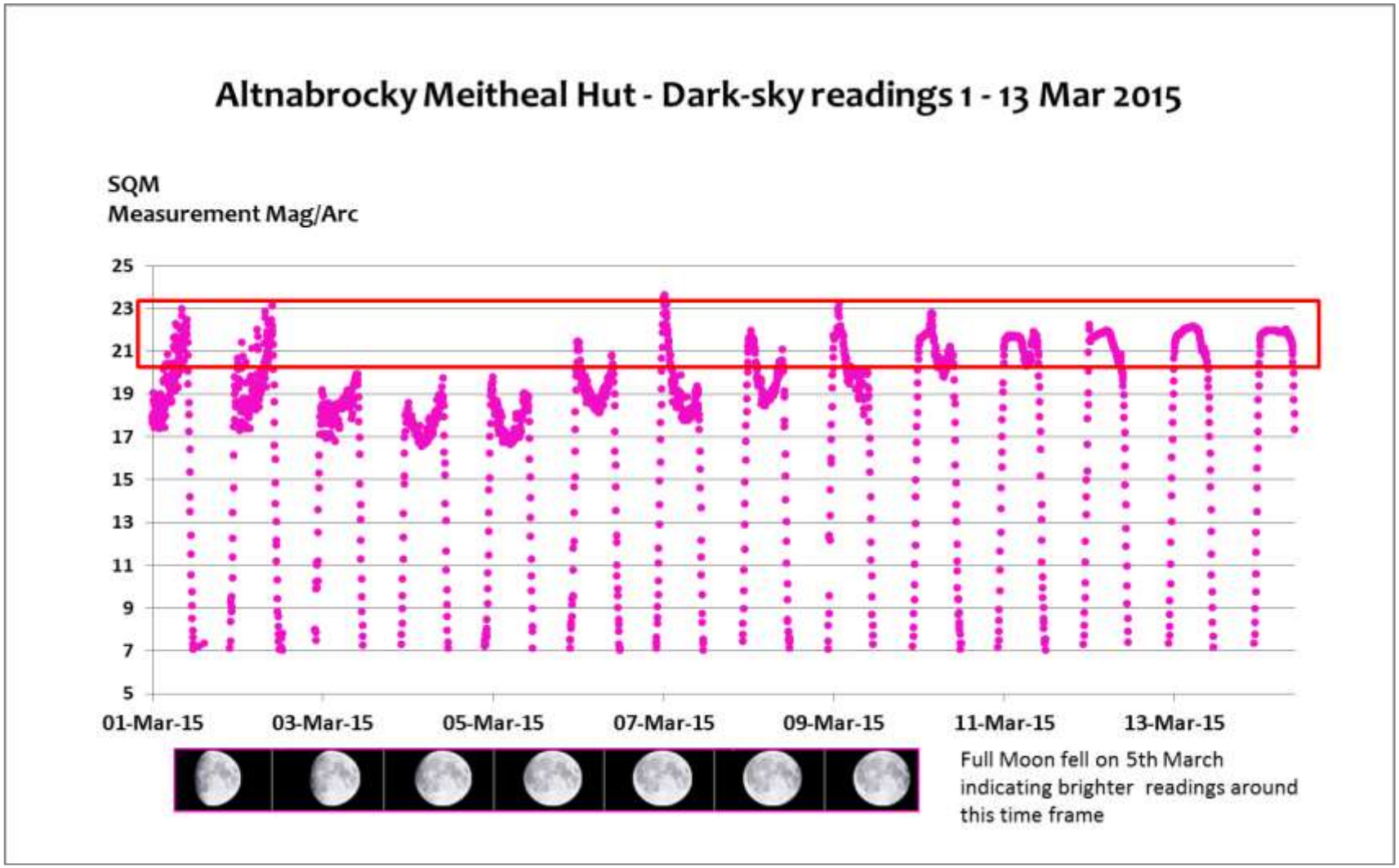


Figure 22: Altnabrocky Hut SQM readings 1-3 Mar 2015

Results from Dark-sky Survey Readings:

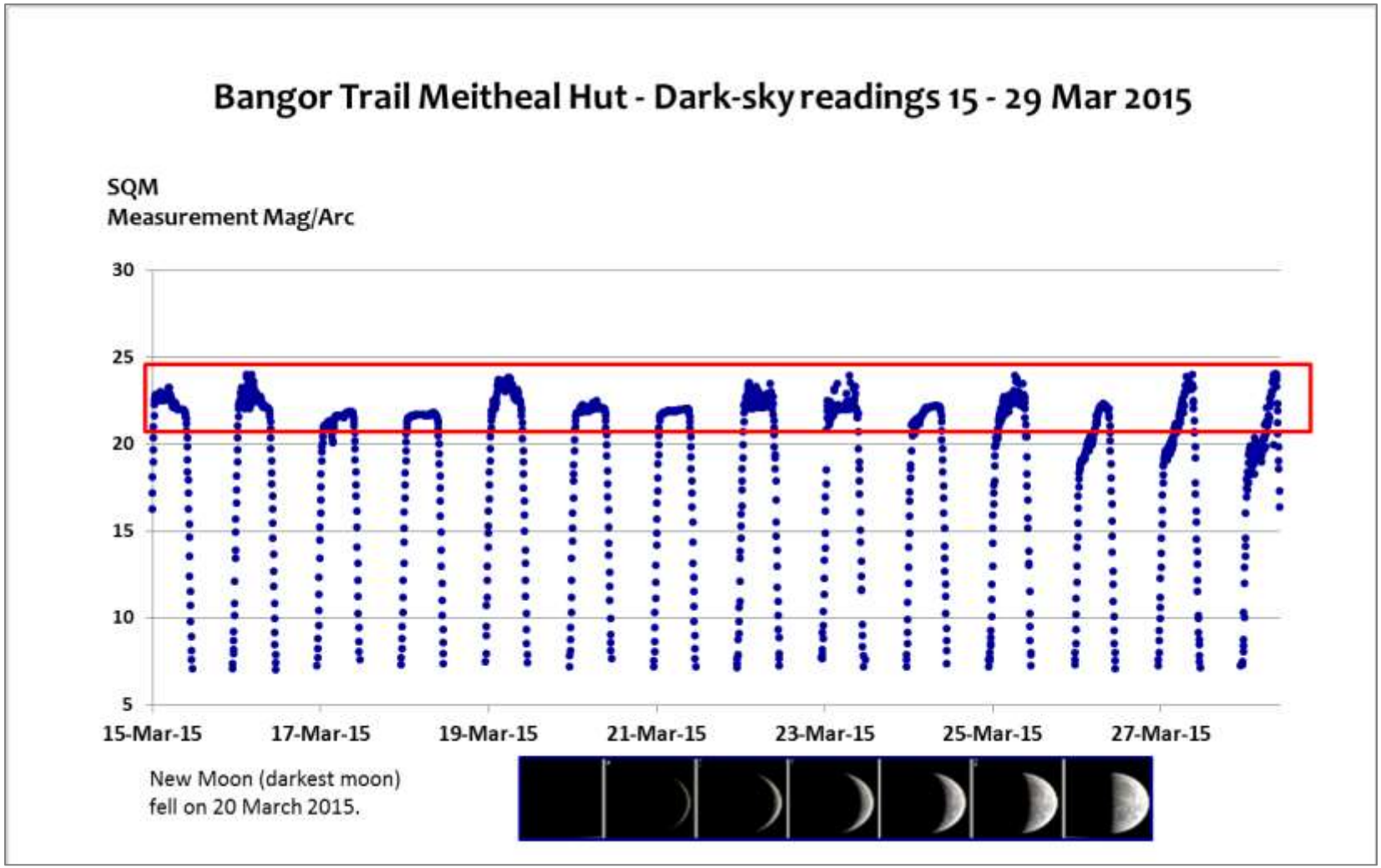


Figure 23: Bangor Trail Hut SQM readings 15-29 Mar 2015

4.3.2 Interpreting the chart data

A number of factors contribute to how dark the night sky is, including the moon, milky-way, airglow from gases in the atmosphere, and the largest contributor – light pollution from man-made sources of illumination. Readings showing a smother arc line indicate a clearer night, whereas those with a scattered line indicate that the weather on the night in question was cloudy. Cloud cover reflects light, which can adversely affect readings in otherwise very dark locations.

The charts also include information on the lunar cycle to explain why the readings fluctuate throughout the period displayed. As a point of reference, a new moon (i.e. the darkest moon), fell on 18th February 2015, and the graphs indicate darker skies at that time.

The vertical axes illustrate the magnitudes per square arc second (mpsas). As indicated previously, the higher the number; the darker the sky reading. Therefore, the most significant readings for this research are those highlighted by the red rectangle.

In the very darkest places the limit of the device comes from the brightness of the stars overhead and so, even in sites free of light pollution, readings over 22.0 should not be expected (Owens, 2012). Readings retrieved that are much darker than 22.0 are likely to be from shaded or clouded areas.

4.3.3 Results from Handheld SQM Meters

This section presents the results from the handheld SQM-L meters. Two of these units were available to the study, and were used by the researcher and the Mulranny Environmental Officer. These readings were taken at deliberately random locations surrounding the BCNP site and nearby towns of Newport and Mulranny, to gain contrasting light measurements. Averaged results are presented below in a simple table format, due to the low volume of data (only 6 readings per location):

Table 3: Handheld SQM Readings

Date	Co-ordinates		Location description	SQM Average
20/02/2015	54.02456022	-9.82360939	Visitor Centre CP*	20.64
20/02/2015	53.95540186	-9.79208807	Claggan Boardwalk*	21.09
02/03/2015	54.025359	-9.826741	Ballycroy village	18.78
08/03/2015	53.88939771	-9.52474157	Newport Road Weir (bend)	21.01
08/03/2015	53.88463623	-9.54614023	Newport town- T Junction Rd	18.28
08/03/2015	53.88721622	-9.54480986	Kellys Garage Newport	14.55
18/03/2015	53.95540186	-9.79208807	Claggan Boardwalk*	22.37
18/03/2015	53.90778978	-9.77477448	Mulranny Greenway	19.48
21/03/2015	54.00029091	-9.74340336	Lungandarragh *	21.58
27/03/2015	54.02327298	-9.81930303	Mulranny Greenway	18.14
27/03/2015	53.91942892	-9.79529262	Mulranny Fisheries	17.86
27/03/2015	53.95540186	-9.79208807	Claggan Boardwalk *	18.90

** Locations featured on map in Figure 16*

It is notable that the readings taken in the Ballycroy village area were quite bright, in comparison to other locations. The researcher noticed several light sources when taking the recordings in the village, such as local security lighting from the licensed premises and structural feature lighting from the cemetery. These are sample observations that would be included in a future lighting audit. Some adjustments may be necessary to maintain the consistency of high quality readings across the region.

This brings the Dark-sky Survey section to a close and the Results Chapter now moves to the next section, which is the Outline Feasibility Study.

4.4 Outline Feasibility Study

The scope of this Outline Feasibility Study is to prepare a report for the consideration of BCNP as a suitable site for Dark-sky application. A description of the site itself is detailed in section 3.2.1 of the Methodology Chapter. There are many aspects to the application of a Dark-sky application form. It is necessary to ensure the region qualifies for astronomical viewing, and this has been dealt with in the Dark-sky Survey section of this chapter.

The contents of this exploratory research section were derived from informal communications with Dark-sky places in the UK and Kerry, and from a review of their application submissions to the IDSA. The results of which were transcribed into note form and collated into the most significant themes.

4.4.1 Dark-sky Eligibility

The guidelines for eligibility of Dark-sky status were updated by the IDSA in October 2014 and apply to any submission received after 23rd March 2015. The criteria for eligibility of a Park versus a Reserve is summarised in Table 4. This demonstrates that the measurement of darkness is only one aspect of the qualifying criteria and commitment required.

Therefore, the capacity for continuous compliance with Dark-sky qualifying criteria must be a sustainable objective for the management team taking on the application.

Table 4: Dark-sky Eligibility

Minimum Eligible Criteria set by the International Dark-sky Association	**Dark-Sky Park**	**Dark-Sky Reserve**
All protected lands, managed by state or local agencies & private lands whose owners consent public access to designated areas	YES	
The **CORE** of the proposed site must be a public or a private land protected for scientific, natural, educational, cultural, Heritage and/or public enjoyment;		YES
No minimum size for CORE ZONE but boundaries of any protected site should be fully included.		YES
Peripheral area is min 700m2 or area sufficient to mitigate 80% of current /future LP threats		YES
Accessibility to the core area at night	YES	YES
Core must fit into Gold, Silver or Bronze	YES	YES
Commitment to a comprehensive Lightscape Management Plan (LMP) through park/development	YES	
At least 67% of lighting to comply with LMP at the time of application to IDSA.	YES	
LMP to be adopted by 80% of communities within entire zone		YES
At least 67% compliance with LMP within core zone		YES
Examples of public and private light installations that comply within each community in reserve. Upgrade at least 10% of fixtures outside core.		YES
Set leadership example through installation of dark-sky friendly projects (for example observatory).	YES	
Programme for future night sky friendly lighting		YES
State-agency recognition of the protected area		YES
After approval; educational outreach programmes (minimum of 4 events per year).	YES	YES
Annual Reports confirming continued compliance post-approval	YES	YES

The two columns to the right hand side of the above criteria have been completed to indicate whether the requirement is for a Dark-sky Park, a Dark-sky Reserve, or both.

Having summarised the eligibility criteria for reserves and park zones, the next aspect of consideration is the type of designation sought for the site selected.

4.4.2 Type of Application

The applications reviewed included both Dark-sky parks and Dark-sky reserves. As discussed in the literature review and illustrated above, a reserve area would be more expansive than a park and involve several landowners. The land mass should normally, although not exclusively, be of approximately 700 square kilometers in size. It would consist of two regions; "core zone" of exceptional darkness meeting the minimum sky quality measurements; and an extended "buffer zone" supporting these values and of a similar standard.

Originally it was envisaged that the BCNP site would apply via for Dark-sky park status. Thus only one landowner (BCNP) would be involved and management of the lightscape would be relatively straightforward. Given the limited nature of this study and the manpower available, the least administrative approach would seem the obvious choice. However, the land non-contiguous land boundaries of the BCNP make this preferred option more challenging.

A Dark-sky application must commit to a lightscape management plan ("LMP") with a conservation approach and identify any potential threat from light pollution. In theory, neighbouring landowners could install lighting at a future point that may infringe upon the quality of the night skies of the park. The largest neighbouring landowner is Coillte, who recently opened the adjoining Wilderness Park. Other bordering landowners are farmers and some commonly owned land. It is unlikely that light pollution would pose a future threat from

these neighbours. However, agreement on a policy will need to be reached before committing to a LMP involving multiple parties. Similar issues were encountered and overcome by Northumberland National Park and its neighbour; Kielder Water & Forest Park. Although, more than one landowner was involved, they considered many options including separate Dark-sky parks, a Dark-sky Reserve, and a joint application for a Dark-sky Park. Eventually, they opted for the latter, a single Dark-sky Park application, which offered better protection of the night sky through the management of a one large core zone.

This study has made preliminary enquiries with the IDSA regarding the BCNP application and received encouraging feedback. It seems a Dark-sky Park would be more appropriate, at least initially. This could then be expanded to a Dark-sky Reserve at a future point. Local landowner commitment and involvement would still be required, however, the entire area is already protected under legislation for Natura 2000 sites. The requirements for Dark-sky status would be no more onerous than existing regulations for the protected habitats.

4.4.3 Key Challenges

4.4.3.1 Lightscape Management Plan

All of the Dark-sky places contacted in the scope of this research identified the preparation of the aforementioned Lightscape Management Plan, as a key challenge in the application process. This technical document requires a complete audit of existing lighting infrastructure within the selected site, together with a management plan to ensure lighting remains compliant. Most of the dark-sky places reviewed engaged a professional lighting consultant to

prepare their LMP. This is where those entities incurred the bulk of the application expenses. The Kerry International Dark-sky Reserve was the exception. In this instance, the project manager prepared the LMP and lighting audit, with a considerable investment of time (J Ormonde 2015, pers. comm., 22 Jan).

In the course of this research, several efforts were made to obtain an inventory of the public street lighting in place in towns surrounding the selected site, as an indicative baseline. The local lighting contractor for Mayo County Council and the council engineers indicated a willingness to assist. However, it was not possible to obtain the information prior to the end of this research period.

Regardless of who prepares the lighting audit and LMP, it will require the co-operation and support of the local community. Gathering this information will require the survey of residential, and public, lighting and engineers in the UK found some home-owners refused to participate. Therefore, such a survey must be conducted with sensitivity, and this leads to the next challenge. Raising awareness through involving the community with participation and ownership of the dark-sky concept.

4.4.3.2 Raising Awareness

The issue of awareness of light pollution has been examined in the results section under the Awareness Questionnaire. The process of explaining light pollution and its impact, and potentially asking local residents to make adjustments to their lighting may be seen as intrusive. The approach used to raise awareness is, therefore, critical. The applications reviewed in this study

feature Outreach Programmes for the local communities. This is an important part of the eligibility for achieving, and maintaining, Dark-sky status. Initiatives such as the "Star-Markers" programme, involves training local people to conduct basic astronomy tours (D Wise 2015, pers. comm., 26 Jan). There is a considerable amount of work required to raise awareness through outreach and education. However, indications show that, once the local community is fully involved, it is likely to act as an ambassador for the Dark-sky zone (R Coulthard 2015, pers. comm., 26 Jan).

4.4.3.3 Local Astronomy Club

There is no active astronomy club or society within the Ballycroy region, nor in fact, in County Mayo. This study reached out to prominent astronomers in Ireland for assistance in locating the nearest club or society. The relevance of identifying a local astronomy club is to ensure the interest in maintaining Dark-sky status is sustainable in the longer term. In the course of this study, the researcher found genuine local interest in developing the Dark-sky initiative. However, there is undoubtedly a lack of expertise in the field of Astronomy. This is a significant challenge to overcome and, as far as this researcher has found, every other successful Dark-sky application has had the support of an active local Astronomy club.

As a trial event, the researcher organised an introductory astronomy night in Ballycroy Community Centre to encourage local interest, and this was well attended. It should also be noted that a group of six members have recently

formed an astronomy society and plan to develop their knowledge base in support of the Dark-sky initiative.

4.4.3.4 Funding

In the case of the UK dark-sky places, funding was secured through, inter alia, charitable trusts, grants, donations, and National Park budgets. In contrast, the Kerry International Dark-sky Reserve received no governmental funding and relied on voluntary work and donations to support the initiative. Preliminary enquiries by the Ballycroy Community Employment Officer indicate that there may be some funding for this project through the EU Rural Alliances Scheme.

4.4.3.5 Sustainability

Achieving a dark-sky award is undoubtedly an attractive addition to off-season tourism. It is a relatively fast and inexpensive initiative that can attract significant attention to the region. However, sustainability is one element that should not be overlooked in the process. The Dark-sky site should have a strong sense of compatibility with the surrounding landscape and be intrinsically valued by its inhabitants and neighbours. The Northumberland Dark-sky Park application came about after recognition that it was one of the most tranquil places in the UK. This created a strong synergy with the Dark-sky concept and the National Park's objectives. It already had access to an active Observatory at Kielder Water & Forest Park (D. Wise 2015, pers. comm., 26 Jan).

Therefore longevity and a robust plan of sustainability needs to be demonstrated when applying for Dark-sky status.

4.4.4 Key Benefits

4.4.4.1 Tourism Development

The research discussed earlier in the Literature Review Chapter, together with a review of the selected applications for Dark-sky status, indicate that there is a growing market for astro-tourism. It was not possible to gather statistics to illustrate an increase in tourism numbers for all of the successful Dark-sky places featured in this study. However, several commented on the significant increase in media attention gained by the Dark-sky status. They believed this had indirectly boosted tourism numbers to their regions. Many of them also worked closely with their local tourism agency to develop a Star-Gazing destination. This extended to incorporate astro-tourism courses for local businesses, with a particular focus on the winter season, when these businesses would otherwise be quiet. New businesses such as telescope hire and Dark-sky Safaris have also been developed on the strength of the Dark-sky award. Surveys taken by Exmoor National Park Authority, show that over 10% of visitors cite the Dark-sky Reserve as being one of the main reasons for visiting the area (D James 2015, pers. comm James, 15 Jan).

4.4.4.2 Education

The establishment of a local dark-sky place will require educational programmes to be devised on the topic of astronomy. This is a science-based subject and lends itself well to develop an interest in physics, mathematics, the natural world and many other educational topics. School visits, field studies and participation in star-gazing events feature regularly in the programmes of

existing Dark-sky places, many of them from facilities such as an Observatories and Planetariums.

4.4.4.3 Wildlife and the Environment

Each of the Dark-sky applications reviewed has included information on the local flora and fauna of the area. The BCNP already hosts many nocturnal species such as badgers, bats, foxes and pine martens. The Programme of Events for BCNP already includes a "Bat Walk" tour and this would complement the Dark-sky initiative very well.

Implementing a plan to control light pollution will enhance and support the objectives of the National Park for the protection of these species' habitats.

Investment and attention to improved lighting schemes will also contribute to a reduction in energy waste and carbon emissions to support environmental objectives.

4.4.5 Astro-Photography

Some outstanding astro-photographs have been featured in the applications of Dark-sky places in the UK and Ireland. These pictures reinforce the visual beauty of the night-skies and support the need to preserve areas of pristine quality. Through this study, a local astro-photographer has been contacted and has agreed to participate in the project to prepare a Dark-sky application for BCNP. This is a very positive indication of local support and a willingness to volunteer services for the application.

4.4.6 Official Support and Project Stakeholders

Another aspect of the application is to provide documentary evidence, in the form of letters to the project management team, showing local support for the designation. The content of this varies from application-to-application. However, examples would be letters from local politicians; regional and national authorities; environmental groups and national governing bodies.

At the time of writing, the main stakeholders who will need to become involved in this project are;

- National Parks and Wildlife Services, namely the Ballycroy National Park management team.
- Coillte and neighbouring landowners
- Community Representatives from Ballycroy and surrounding areas.
- Mayo County Council
- Mayo County Development Board/South West Mayo Development Co.
- Fáilte Ireland
- The International Dark-sky Association

Several of these entities have already indicated willingness to become involved through preliminary enquiries made in the course of this study.

4.4.7 Estimated Costs and Timeline

It is estimated that each application for Dark-sky status can take between 12-24 months to prepare. The timeline should not be underestimated, due to the number of parties involved. Indicative costs have been included using the experiences discussed with other Dark-sky award holders. However, much of this is unique to each application and BCNP is no different. The costs incurred

will depend upon the type of application, how many drafts are required, whether staff or external consultants are involved, and also how much time could be contributed on a voluntary basis.

Nevertheless, if funding is obtained, consultants could be brought in to manage the application and submission process. This study has noted that there is a Dark-sky consultant based in Ireland (County Kerry) who could provide this service and possibly expand it to include the LMP.

Technical equipment (SQMs) will need to be purchased to continue the sky-quality monitoring. It should be noted that there is no fee charged by the IDSA to process and approve/disapprove an application for Dark-sky status.

A suggested milestone and timeline is provided in the Gantt Chart[4] in Table 5.

[4] *Gantt Chart – a summary project schedule developed by Henry Gantt c. 1910*

Table 5: Draft timeline & Costs

Project Feasibility		Cost	February	March	April	May	June	July	
Dark Sky Survey									
	Initial visit with expertise	200							
	Loaned SQM equipment survey								
	Purchase of SQM (both fixed & handheld)	800							
	Photographs for promotion	0							
	Launch of Facebook / Social Media								
		1000							
IDSA Application (post feasibility, prior to submission)									
ASSUMING LOCATION SUFFICIENTLY DARK TO PROCEED TO APPLICATION STAGE									
Funding and Resources									
	Agree key stake holders & project team								
	Review potential funding opportunities								
Community Engagement & Publicity									
	Training & events	300							
	Photographs for launch of campaign	250							
	Visit to existing Dark Sky Reserve								
	Leaflets and raising awareness	500							
	Training for volunteers	250							
	Local tourism initiatives								
	Publicity Campaign	500							
		1800							
Lighting Management Plan									
	Lighting audit	1500							
	Lighting guidelines based on Application	2000							
	Preparation of Light Mgt Plan	1000							
	Fixture & fittings upgrade	700							
		5200							
Application Preparation									
	Continuous SQM Monitoring								
	Preparation of application								
	Consutant review of application (if necessary)								
	Review and comments from IDA rep								
	Submission of final application								
Programme sustainable intiatives									
	NPWS website update								
	Educational programme								
	Future event planning								
	Potential sites for astro-viewing within park								
	Signage and information stations								
	Annual report and IDA update								

March 2016 Target for Submission

4.4.8 Conclusion of Outline Feasibility

The Outline Feasibility Study has looked at the significant patterns that emerged from a review of the applications and communications with the Dark-sky places of the UK and Ireland. Despite the brevity of this section, it has examined the main challenges and benefits the BCNP can expect to encounter in its pursuance

of Dark-sky status. It appears that much of the criteria can be met, but this is only the beginning of the process. In order for the Dark-sky site to maintain longevity, there must be a strong management structure in place. At the point of writing, it is not clear exactly who will be the named applicants in submission. However, there is local support from both community groups and from state-agencies such as the NPWS, and this is critical.

The Visitor Centre at BCNP is an ideal location to establish a suitable star-gazing spot, assuming local lighting adjustments can be made to ensure compliance. It also has excellent access for wheelchair users and can host a variety of indoor events, such as light pollution and educational talks. Access to viewing points at night-time (a critical factor of eligibility) would also be possible.

Therefore, a collaborative steering group, formed between the key stakeholders, would be an ideal way to progress.

4.5 Summary of Results Chapter

This results chapter has presented the three areas of research conducted in the study. Findings for the Awareness Survey established that the participants were largely rural residents and, therefore, unlikely to be exposed to light pollution. Nevertheless, they were not particularly aware of its effect on the socio-environmental factors presented.

The Dark-sky Survey, however, was designed to return more empirical results. These findings showed that all fixed meter locations produced dark-sky qualifying readings. The handheld meters showed lower readings, indicating that there is work to be done in some areas to improve the lighting standards. However, mitigating factors affecting the sky-quality included; the time of night, cloud conditions on the night(s) in question, and proximity to light sources.

Lastly, the findings for the Outline Feasibility Study produced a realistic assessment that BCNP is an appropriate site, and could satisfy the management and qualifying criteria, for a Dark-sky Park application.

This concludes the Results chapter and this study now moves to the Discussion Chapter.

5. Discussion

5.1 Introduction

This chapter will discuss the results of this study and their relationship to the reviewed literature on the subject matter. This allows the researcher to draw conclusions based on the research questions and hypothesis.

The subjects of "Light Pollution" and "Dark-sky places" steered the researcher's focus in establishing the hypothesis. The common theme between these two topics was the preservation of the night-time sky. Therefore, the structure of this chapter will discuss the main themes associated with preserving the night-time sky, together with the results of the research conducted.

5.2 Awareness of Light Pollution and its effects

A significant area of this research focused on the awareness of light pollution and how it affects our daily life and the natural environment. One of the most striking conclusions this researcher drew from literature on this topic was that our society is simply not aware of the effects of artificial lighting at night. The results produced in the Awareness Survey supported this view, to an extent. Participants were generally unsure of whether street lighting had a positive or negative effect on health, for example. In contrast, in their opinion, street lighting had positive effects on home security and public safety.

This supports the research presented by Atkins et al (1991), which found that public street lighting has an impact on the *fear* of crime, although it may not have an impact on crime itself. The public lighting contractor for Mayo told the

researcher that residents will quickly complain if a streetlight outside their door fails to work (S Corcoran 2015, pers. comm., 19 Feb). Conversely, there is no indication of complaints about light entering their homes throughout the night, nor any concern for the consequences this exposure to LAN may have. In selecting articles for the Literature Review Chapter that were relevant to the hypothesis of this study, the researcher did not specifically include works pertaining to sleep disorders associated with LAN (conducted by the Maynooth University). However, on reflection and the basis of works since reviewed, this would be an area to investigate in further studies on the awareness of light pollution in Ireland.

5.3 Public Lighting and Energy

The authorities responsible for public lighting are under pressure to reduce energy bills, whilst ensuring the public's perception of safety is maintained [through street-lighting] (Echo News, 2015). Schemes for part-night lighting risk public complaint if a crime is committed during the dark hours. Therefore, it seems that the solution is to ensure public lighting is efficient (i.e. full-cut off[5] type), ecologically friendly (i.e. does not contain blue rich hues of colour), and that part-night lighting is trialled for public response. If this is operated in conjunction with an educational awareness campaign, it stands more chance of success.

[5] Full cut-off lighting is designed to control light pollution and light only the area intended.

Updating our public lighting for the Dark-sky Application may not be as big a challenge as it appears. As indicated in the literature review chapter, Ireland is already committed to the EU Directive to reduce its energy by 20% before 2020. Lighting upgrades are becoming noticeable in our street-scapes as a result. The South West Kerry Dark-sky application submission benefited from the county council's commitment to upgrade to energy efficient lighting fixtures (Ormonde, 2013). The researcher has not been able to ascertain confirmation of a similar plan for Mayo, although informal communications indicate that such upgrades may be on the way.

5.4 Domestic and Commercial Lighting

The Awareness Survey revealed that a large number of participants had exterior lighting fitted to their property. This appears to be prevalent, regardless of whether street lighting is nearby. Research included in the Literature Review Chapter indicates that this has the potential for a security compromise, rather than an enhancement. Incorrectly fitted lighting can cause glare and create a shadow to hide, not reveal, an intruder (as illustrated in Figure 2). The researcher noticed domestic lighting fixtures are available in many local stores, including supermarkets. This presents another avenue to tackle through awareness and education. If retailers could be persuaded to stock night-sky friendly lighting (as advocated by the IDSA) with guidelines to prevent poorly fitted home lighting, then perhaps light pollution from domestic sources could be reduced.

This study has not approached the subject of light pollution originating from commercial lighting. This subject is vast and outside the constraints of this research. However, participants in the Awareness Survey were asked if commercial lighting, inter alia, contributed to excessive lighting in their area. The results indicated that it was not considered significant, even from residents in towns. The researcher expected that this might be higher, having noticed commercial lighting to be reasonably prevalent.

5.5 The Dark-sky Quality of BCNP

The Dark-sky Survey showed that all fixed-meter positions produced results that could meet IDSA Eligibility. This result was anticipated, although the frequency of such high quality SQM readings was a surprise, even for this rural location. Prof. Espey, a recognised expert in conducting Dark-sky surveys, acknowledged the readings were impressive.

In contrast, slightly disappointing results came from the SQM-L handheld readings taken in Ballycroy Village. As the overall region is certainly very dark, a small amount of light pollution in a rural area has a more significant visual impact. Security and light installations were very noticeable and negatively affected the handheld readings. Newport Town had similar results, although, it should be noted that haze and cloud cover exacerbated the readings taken.

Taking a positive view, these examples can provide a “before and after” for the IDSA submission. Furthermore, the area has a community employment scheme, which offers a potential resource to upgrade or retrofit non-compliant lighting

fixtures. This would demonstrate the community's capacity to acknowledge and address light pollution in the region.

The Dark-sky quality readings taken by the fixed-meters are notably better than the aforementioned handhelds. The fixed-meter readings are comparable to those obtained by several of the Dark-sky places included in the Outline Feasiblity Study. In fact, they compare favourably to sites that achieved a Gold tier classification from the IDSA (i.e. readings exceed 21.7 Mpsas). This is a very positive start to the application process. More survey work will need to be done, but the baseline data recorded in this study, is a promising indication that the sky quality of the proposed site is exceptional.

5.6 Choice of Methodology

Despite the encouraging results above, the researcher acknowledges that the number of locations from which readings were taken, is less than the IDSA's recommendation of twelve. In reviewing other applications for Dark-sky status, the researcher noted that SQM readings had been taken from a much larger number of locations (over 100 sites in some cases) (Wise & Rowark, 2013). It should be noted that the handheld SQM-L models, used by most of the UK applicants, are convenient for covering multiple locations. The disadvantages of using this model only, is that only a short period of time is recorded at each location, and the data is recorded manually; thus subject to human error.

The researcher addressed the difference in practices by contacting the IDSA for guidance. The response approved the approach adopted by this study, i.e. the

use of SQM-DL-LU models to log continuous data, supported by handheld meter readings in random locations. Additional fixed-meter locations can be included to record further continuous data for the actual Dark-sky application submission.

5.7 Local Astronomy

In the Awareness Survey, participants clearly indicated that they would have an interest in Astronomy programmes, if available locally. The research presented in the Outline Feasibility Study, highlighted the lack of an Astronomy Club, or local expertise. This is an area where the BCNP region falls short of the other Dark-sky places examined. It will take considerable commitment from the local community to establish an active Astronomy Club, although if the region achieves a Dark-sky status, more opportunities will be created to nurture this subject.

It is worth reporting that the Ballycroy Community officer has made some enquiries pertaining to the cost of an Observatory. Funding may be possible for this as a community and educational facility. This would be an excellent example of commitment to developing astronomy in the region. It would also enhance the educational possibilities that the initiative brings.

5.8 Future Threat of Light Pollution

The results of the Outline Feasibility Study established that a critical part of a Dark-sky application is the LMP. The future threat of light pollution must be addressed within this plan, and local support is essential. Given that the local habitats are protected under Natura 2000 sites, it is unlikely that there would be

any significant development of residential housing, or commercial/industrial premises, to impact on the preservation of the night-sky quality. However, in the absence of legislation to control light pollution (discussed in the next section), it is important to ensure preservation of the night-time sky is included in County Development Plans.

5.9 Policy and Legislation

In Ireland, neither legislation, nor policy is an available tool to combat the effects of light pollution, and this has been a recurring theme in the Literature Review Chapter. There is clearly a need to implement policy, but this will not happen overnight. Following comments on legislation from the Department of the Environment, the researcher considered whether a top-down approach (i.e. government led) would be the correct route to effect action. It seems that responsibility is attributed to all levels; individually, locally, nationally and internationally. Collective responsibility is a more realistic route to take.

Given that the attractions of Dark-sky tourism have been raised at government level, as mentioned earlier, this may assist in raising the profile for policy implementation. In addition, conservation authorities such as the Heritage Council should be approached to recognise Ireland's Dark-skies as part of our national heritage.

These points will be included in the Recommendations section of the next Chapter.

5.10 Summary of Discussion

This Discussion Chapter has examined the findings for this study, in the context of the original hypothesis and research design.

The results support the hypothesis that the night-time sky is worth preserving. Measures to control light pollution, through awareness, policy implementation, and the development of Dark-sky places, would not only benefit our visual appreciation of the stars, but would also contribute to our environmental conservation efforts.

The questions raised in Chapter 1 have been addressed throughout this research and, ultimately, demonstrated in the Results Chapter. The findings identified impressive results from the Dark-sky survey that merits continuous data recording.

This study has taken the first steps in preparing for a Dark-sky application on behalf of the BCNP region. It has established strong links with the NPWS, the local community, and with other key stakeholders, including the IDSA. It is anticipated that the project will continue after the completion of this work.

With that in mind, the study moves to its final Chapter: Conclusion and Recommendations.

6. Conclusion and Recommendations

"I was grounded…..while you filled the skies,

I was dumbfounded by truth…..you cut through lies,

I saw the rain dirty valley…..you saw Brigadoon,

I saw the crescent…..you saw The Whole of the Moon"

[Mike Scott, The Waterboys, 1985]

This dissertation began with the words of a French Physicist, Jean Perrin. He philosophically questioned; what would science have achieved without a view of the stars? This dissertation has examined views; our view of the stars, and our views on light pollution and how it affects us. Unlike other pollutants, light pollution is largely hidden from our cognitive view, we think of its effect in terms of astronomy. We do not consider the extent of its impact to our health, our biodiversity, or our environment. However, we can be optimistic as light pollution is relatively easy to fix, but changes are required to put solutions into effect. Therefore, the recommendations presented below relate to the challenge of tackling light pollution and the preservation of our night-time skies, through the creation of a dark-sky place in County Mayo.

6.1 Recommendations

- In the absence of legislation, action should be taken at national level by the Department of the Environment to promote Awareness of Light Pollution. A framework such as the "Leave No Trace" campaign would be a good example to follow. Improving education, on the impact of light pollution, would encourage collective responsibility at all levels.
- Submissions should be made to Local Authorities to include light pollution prevention measures in County Development Plans updates.
- Research on light pollution in an Irish context is limited, and there is scope for further study in this area.
- In relation to preservation of the night-time skies, Nightscapes in Ireland should be included for protection under the Heritage Act.
- Furthermore, the application for Dark-sky status should be prepared for the BCNP, and a local steering group should be established.
- The preparation of the LMP should involve community groups to adjust or retrofit compliant light fixtures for local residents.
- Further events relating to Astronomy should take place in the BCNP region. The existing local interest should be encouraged with a series of educational and cultural events relating to star-gazing.

The recommendations bring this chapter, and also this dissertation, to an end. In the absence of closing remarks, the reader is invited to simply appreciate the majestic Milky Way, in a view of the night-time skies of County Mayo.

Figure 24: "Twisted Sisters" by kind permission of Brian Wilson

Worth preserving? The decision is in our hands.

7. Bibliography

Atkins, S., Husain , S. & Storey , A., 1991. *The Influence of Street Lighting on crime and fear of crime*. Home Office.

Bailey, M.E. & Apostolos, C.A., 2007. Light Pollution and the City of Armagh. *Armagh Observatory*, August.

Bat Conservation Ireland, 2010. *Bats and Lighting*. Guidance Note. Bat Conservation Ireland.

BBC, 2014. *BBC News*. [Online] Available at: "http://www.bbc.com/news/uk-england-30176339" [Accessed 27 November 2014].

Beatty, K.J., 2010. Saving the Night Sky. *Sky & Telescope*, May.

Bishop, C.A., 2014. Chile Gets Rid of the Blues. *Nightscape*, July.

Bradley, T., 2012. *Protecting the Night Sky on the urban fringe of Dublin*. Dublin: An Taisce.

Chepesiuk, R., 2009. Missing the Dark: Health Effects of Light Pollution. *Environmental Health Perspectives*.

Claudio, L., 2009. Switch on the Night: Policies for Smarter Lighting. *Environmental Health Perspectives*, January.

Clover, C., 2010. The safety con lurking under the Street Lights. *The Sunday Times*, 14 November.

Bibliography

College of Policing Limited, 2008. *College of Policing*. [Online] Available at: http://whatworks.college.police.uk/Research/Briefings/Documents/What%20Works%20Street%20Lighting%20final%20version%20June%202013.pdf [Accessed 8 March 2014].

Deda, P., Elbertzhagen, I. & Klussmann, M., 2007. *Light Pollution and the impacts of Biodiversity, Species and their Habitats*. La Palma: Starlight Initiative Conservation of Migratory Species of Wild Animals.

Echo News, 2015. *Echo News*. [Online] Available at: http://www.echo-news.co.uk/NEWS/11724535.Police_commissioner__Street_lights_off_means_a_better_night_s_sleep/?action=complain&cid=13608527 [Accessed 1 February 2015].

Espey, B., White, A. & McCauley, J., 2012. *Light Pollution in Ireland*. Draft. Dublin: Trinity College Dublin. Draft Document on light Pollution in Ireland.

European Commission, 2011. *The EU Climate and Energy Package*. [Online] Available at: http://ec.europa.eu/clima/policies/package/index_en.htm [Accessed 27 March 2015].

Farrington, D.P. & Welsh, B.C., 2008. 251 *Effects of improved street lighting on crime: a systematic review*. Home Office Research, Development and Statistics Directorate.

Bibliography

Galloway, T., Olsen, R.N. & Mitchell, D.M., 2009. The Economics of Global Light Pollution. *Ecological Economics*.

Griffiths, M., 2013. A dark sky survey in Wales. *British Astronomical Association*, pp.194-96.

Kempenaers, B., da Silva, A. & Valcu, M., 2015. Light pollution alters the phenology of dawn and dusk singing in common European songbirds. *Philosophical Transactions B: The biological impacts of artificial light at night: from molecules to communities*, 370(1667).

Klinkenborg, V., 2008. Our Vanishing Night. *National Geographic Magazine*.

Kyba, C., Hanel, A. & Holker, F., 2014. Redefining efficiency for outdoor lighting. *Journal of Energy and Environmental Science*.

Lane, M., 2011. Stargazing and dark sky tourism. *BBC News Magazine*, 3 January.

Longcore, T. & Rich, C., 2004. Ecological light pollution. *Frontiers in Ecology and the Environment*, 2(4), pp.191-94.

Lucey, A., 2014. Kerry's night sky: 'It's like a punch in the stomach'. *Irish Times*, 15 July.

Marchant, P., 2010. What is the contribution of street lighting to keeping us safe? An investigation into a policy. *Rad Stats Journal*, (102).

Bibliography

McGreevy, R., 2012. Moving to the dark side. *The Irish Times*, 20 September.

McNally, D. & Morgan-Taylor, M., 2012. Dark skies in the UK. June. p.3.25.

Morgan-Taylor, M., 2013. The Regulation of Light Pollution in Europe. In *11th International Symposium on Sustainable Healthy Buildings*. Korea, 2013. Martin Morgan-Taylor.

Oireachtas Debates, 2014. Tourism Promotion. In *Dail Debates*. Dublin, 2014. Oireachtas. Extract from http://oireachtasdebates.oireachtas.ie/debates%20authoring/debateswebpack.nsf/takes/dail2014020400081?opendocument.

Ormonde, J., 2013. *Application to the International Dark-Sky Association for consideration of a Dark-Sky Reserve in South West Kerry, Ireland*. Waterville: Kerry Dark Sky Reserve.

Owens, S., 2012. *Dark Sky Diary*. [Online] Available at: http://darkskydiary.wordpress.com/2012/01/19/the-bortle-scale-a-flow-chart/9" [Accessed 2 December 2014].

Owens, S., 2012. Star trekking: a quest for darkness. *The Guardian*, 13 April.

Praeger, R.L., 1937. *The Way that I Went*. Dublin: Collins.

Bibliography

Robinson, T., 2008. *Connemara; The Last Pool of Darkness*. 1st ed. Dublin: Penguin Ireland.

Rosenthal, E. et al., 1984. Seasonal Affective Disorder A Description of the Syndrome and Preliminary Findings With Light Therapy. *Journal of American Medical Association*.

Ruggles, C., 2010. *Portal to the Heritage of Astronomy*. [Online] Available at: http://www2.astronomicalheritage.net/index.php/about/what-is-astronomical-heritage [Accessed 4 April 2015].

Smith, J., 2010. Dark Sky Parks. *New Scientist*, 4 October.

Stevens, R.G., 2009. Light-at-night, circadian disruption and breast cancer; assessment of existing evidence. *International Journal of Epidemiology*.

Stevens, R.G. et al., 2013. Adverse Health Effects of Nighttime Lighting. *American Journal of Preventive Medicine*.

Sustainable Energy Authority of Ireland, 2011. *Energy Efficiency and Public Lighting*. Report. Dublin: Sustainable Energy Authority of Ireland.

Sustainable Energy Authority of Ireland, 2012. *Energy Use in the Public Sector*. Dublin: SEAI Sustainable Energy Authority of Ireland.

Bibliography

Tekatch, A., 2015. *Unihedron*. [Online] Available at: "http://www.unihedron.com/projects/darksky/faq.php" [Accessed 15 March 2015].

The Economist, 2012. The dark ages: Street lighting. *The Economist*, 28 July.

The Heritage Council, 2014. *The Heritage Council*. [Online] Available at: www.heritagecouncil.ie [Accessed 4 November 2014].

UNESCO, 2015. *International Year of Light 2015*. [Online] Available http://www.light2015.org/Home/CosmicLight/Dark-Skies-Awareness.html [Accessed 27 2015 2015].

Walker, H. & Murdin, P., 2003. Dark Skies Action. *Oxford Journals*, 44(6.13).

Wighton, K., 2013. Desparate for a Good Nights Sleep?. *Daily Mail*, 21 October.

Winterman, D., 2012. Light Pollution: Is there a solution?. *BBC News Magazine*, 18 January.

Wise, D. & Rowark, E., 2013. *Application for an International Dark-sky Park*. Northumberland National Park Authority.

Bortle Scale classification

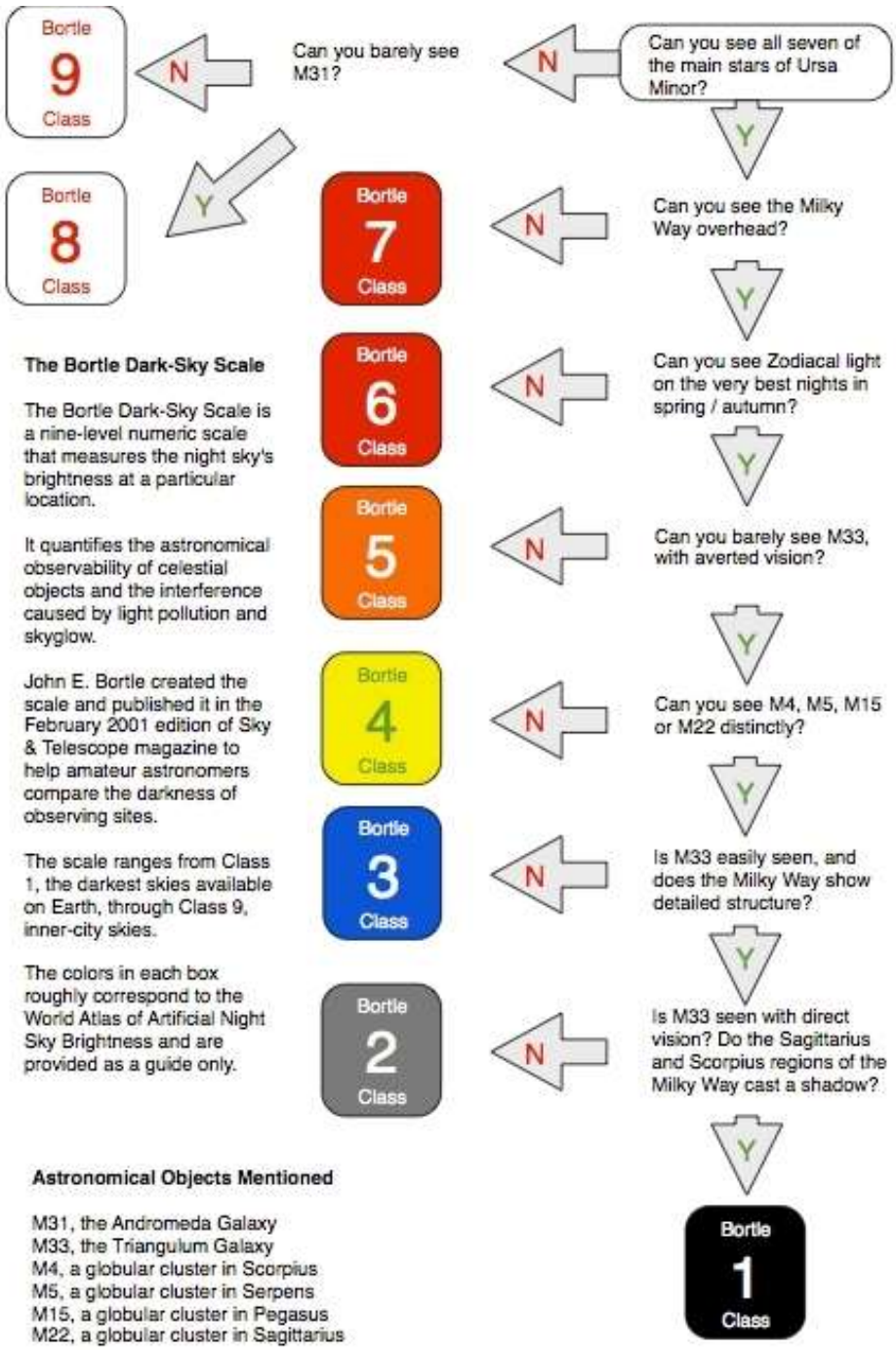


Figure 25: Bortle Scale Flow Chart

Appendix ii

Illustrations of technical Equipment used:

SQM-LU-DL (a fixed position meter)

SQM-L (a handheld Sky Quality Meter)

Explanation of taking dark-sky quality readings.

Appendix iii

Survey on the impact of artificial lighting and night-time sky viewing

This questionnaire is designed to assess general awareness of excessive artificial lighting and the value applied to the night-time sky. It will be collated and used in a study for my dissertation at GMIT Castlebar for 2015. I would greatly appreciate your time in completing the details:

I can be contacted by email georgia@internationalmagic.com
Thank you.
Georgia MacMillan

1. Describe the area in which you live:
   - ○ Rural
   - ○ Village
   - ○ Small Town
   - ○ Medium Town
   - ○ Other _____

2. What is the name of your nearest town_____

3. Please rate how bright you feel the area outside your residence is at night.

	1	2	3	4	5	
Pitch Black	○	○	○	○	○	Bright as day

4. To what extent do the following artificial lights contribute to excessive lighting in your area?

		1	2	3	4	5	
Street Lighting	None whatsoever	○	○	○	○	○	Highly excessive
Car headlights	None whatsoever	○	○	○	○	○	Highly excessive
other domestic premises	None whatsoever	○	○	○	○	○	Highly excessive
Commercial premises (eg. shop signs)	None whatsoever	○	○	○	○	○	Highly excessive
Public buildings	None whatsoever	○	○	○	○	○	Highly excessive
Sports grounds	None whatsoever	○	○	○	○	○	Highly excessive
Car parks	None whatsoever	○	○	○	○	○	Highly excessive

5. Please describe what you think are the main sources of night-time illumination in the area of your residence (you may give several sources)

_____

6. In your opinion, how does public street lighting affect the following?

		1	2	3	4	5	
Home Security (burglary)	Positively	○	○	○	○	○	Negatively
Wildlife	Positively	○	○	○	○	○	Negatively
Energy consumption	Positively	○	○	○	○	○	Negatively
Personal Safety	Positively	○	○	○	○	○	Negatively
Recreation opportunities	Positively	○	○	○	○	○	Negatively
Roads/driving conditions	Positively	○	○	○	○	○	Negatively
Astronomy	Positively	○	○	○	○	○	Negatively
Health Impacts	Positively	○	○	○	○	○	Negatively
Sleep Patterns	Positively	○	○	○	○	○	Negatively

7. What type of external lighting do you currently have on your residence?

- ○ House Light
- ○ Security Light
- ○ Garden Light(s)
- ○ None at all
- ○ Other _____

8. How often would you appreciate the night-time sky/stars?

- ○ Never
- ○ Occasionally
- ○ Often
- ○ Very Often

9. In your opinion, how suitable would your local region be for viewing the stars at night?

	1	2	3	4	5	
Unsuitable	○	○	○	○	○	Highly suitable

10. Would you be interested in the development of educational astronomy programmes if available locally?

○ Yes ○ No

11. Your age group:

- ○ 18-25 years
- ○ 26-35 years
- ○ 36-45 years
- ○ 46-55 years
- ○ 56-65 years
- ○ Over 65 years

Thank you for your time!

Date survey taken:

Appendix iv

Location Name	Meitheal Hut (Altnabrockey)	Visitor Centre	Rangers Office	Letterkeen stone bothy	Meitheal Hut 2 Bangor Trail
Lat	54.05024296	54.02327298	54.06690598	53.98292896	54.003563
Long	-9.608228054	-9.819303026	-9.779507027	-9.561729054	-9.62275
Meter No:	2634 changed to 2369	2629 - now 2628 from 21 march	2628	2369 -now 26342369 as of 15/3/15	
Installed	14-Feb-15	14-Feb-15	14-Feb-15	14-Feb-15	15-Mar-15
01/03/2015	2000+ d/loaded Now 2369	Some data but Cracked Screen	Not downloading, failed 3 attempts	Now 2634	
10/03/2015	Didn't sort gate key in time	data only recorded til 7th March…?	Retrieved (data d/load prob)	Retrieved- data erase not working 2 Mar	
11/03/2015		Wrong screen received.	downloaded data only til 2nd M	Software problems	
13/03/2015		Await correct screen		Software updated & records erased	
14/03/2015	Key accessed will retrieve tomorrow		Data erased - return Thurs	Meter replaced in situ	
15/03/2015	data downloaded. Moved to new spot				1st data. New batteries
21/03/2015		Installed Meter 2628	Removed for new location		
29/03/2015				Why only 300 records. Batteries down. Replaced & reset	Over 2000 records. Batteries still good.

Table 6: Activity Log from SQM Field Trips